Frequency analysis of annual maximum hourly precipitation and determination of best fit probability distribution for regions in Japan

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ABSTRACT

In the design of irrigation and other hydraulic structures, evaluating the extreme rainfall for a specific probability of occurrence is important. The capacity of such structures is usually designed to cater to the probability of occurrence of extreme rainfall during its lifetime. In this study, a frequency analysis of annual maximum hourly rainfall for 15 locations in Japan was carried out using the Expanded Automated Meteorological Data Acquisition System (EA) weather data of 20 years from 1981 to 2000. Eight formulas were used to expect the return period in years of annual maximum hourly rainfall. Five different probability distribution functions (PDFs) were adopted to predict the probability distribution of occurrence of annual maximum hourly rainfall. The goodness of fit was evaluated using Chi-square test. It indicated that the Log-Pearson type 3 (LP3) distribution is the overall best fit PDF for annual maximum hourly rainfall at most locations of Japan.

1. Introduction

Extreme rainfall events and the resulting floods can take thousands of lives and cause billions of dollars in damage. Flood plain management and designers for flood control works, reservoirs, bridges, and other investigations need to reflect the likelihood or probability of such events. Hydrologic studies also need to address the impact of unusually low stream flows and pollutant loadings because of their effects on water quality and water supplies (Stedinger, 1983).

Frequency analysis is used to predict how often certain values of a variable phenomenon may occur and to assess the reliability of prediction. It is a tool for determining design rainfalls and design discharges for drainage works and drainage structures, especially in relation to their required hydraulic capacity. Designers of drainage works and drainage structures commonly use one of two methods to determine the design discharge. One is to select a design discharge from a time series of measured or calculated discharges that show a large variation. Another is to select a design rainfall from a time series of variable rainfalls and calculate the corresponding discharge via a rainfall-runoff transformation (Oosterbaan, 1988). Frequency analysis is also an information problem: if one had a

Abbreviations: P (X ≥ x), probability of occurrence; T, return period or recurrence interval; m, rank of a value in a list ordered by descending magnitude; n, total number of values to be plotted; b, a parameter which is different in different formulas; X_T, maximum value of event corresponding to return period (T); μ, mean of annual maximum hourly rainfall of observed years; δ, standard deviation of annual maximum hourly rainfall of observed years; w, a value of an intermediate variable; z, a value corresponding to an exceedance probability of P; χ^2, Chi-square test; F(x), cumulative density function (CDF); E, expected annual maximum hourly rainfall; Q, observed annual maximum hourly rainfall; i, the number of observations (1, 2, ..., k)

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sufficiently long record of rainfall, flood flows, or pollutant loadings, then a frequency distribution for a site could be precisely determined, so long as change over time due to urbanization or natural processes did not alter the relationships of concern (Stedinger et al., 1993).

Assessing the statistics of extreme rainfall events is important as the frequency of extreme events will affect the design, implementation and operation of measures for preventing floods (Liu et al., 2015). In hydrology, this includes selecting an appropriate probability distribution function (PDF) for assessing extreme rainfall events in regions. If the theoretical PDF fits the actual consecutive hourly, daily, monthly or yearly observed values of rainfall, it can be used to predict the probability of extreme rainfall events in the future. Distribution fitting is the procedure of selecting a statistical distribution that best fits to a data set generated by some random processes. PDF is an important tool for dealing with uncertainty (Khudri and Sadia, 2013). A research by Upadhyaya and Singh (1998) reported that it is possible to predict precipitation fairly accurately by employing different probability distributions for certain return periods although the precipitation varies with respect to space, time and has an erratic nature.

In most cases, the return periods of interest exceed usually the periods of available records and could not be extracted directly from recorded data. Therefore, in current engineering practice, the estimation of extreme rainfall is accomplished based on statistical frequency analysis of maximum precipitation records where available sample data could be used to calculate the parameters of a selected frequency distribution. The fitted distribution is then used to estimate event magnitudes corresponding to return periods greater than or less than those of the recorded events. Accurate estimation of extreme rainfall could help to alleviate the damage caused by storms and can help to achieve more efficient design of hydraulic structures (Olofintoye et al., 2009). Many PDFs used in hydrology are the Normal, Log-Normal (LN), Gumbel, Gamma 2 (G2), Pearson type 3 (P3), Log-Pearson type 3 (LP3) and Weibull distributions (Aksoy, 2000). The Weibull and Gumbel distributions are commonly used for extreme values of hydrological variables. Ogunlela (2001) used five PDFs to analyze frequency of maximum daily and monthly rainfall for Ilorin, Nigeria. The result showed that the LP3 distribution best suited the maximum daily rainfall data while the normal distribution best described the maximum monthly rainfall for Ilorin. Salami (2004) reported the flow along the Asa River and established probability distribution models for the prediction of the annual flow regime in his study. The result showed that the LP3 and Gumbel distributions respectively were recommended for minimum and maximum flows. The applicability of LP3 distribution to flood and maximum rainfall data and its general use in fitting annual rainfall and stream flow sequences was evaluated by Phien and Ajirajah (1984). Nguyen et al. (2002) reported that several probability models have been developed to describe the distribution of annual extreme rainfalls at a single site. However, the choice of an appropriate PDF is still one of the major issues in engineering practice since there is no general agreement as to which distribution could be used for the frequency analysis of extreme rainfalls. Thus, it is necessary to evaluate many available PDFs in order to find an appropriate model that could provide accurate extreme rainfall estimations.

This study aims to study the distribution characteristics of annual maximum hourly rainfall for nine regions including 15 locations of Japan, using different PDFs such as Normal, LN, Gumbel, G2, P3 and LP3 distributions, and determine the best-fit PDF in terms of annual maximum hourly rainfall of 20 years from 1981 to 2000.

2. Observation sites and rainfall data

2.1. Weather observation sites of Japan

The regions of Japan are mainly divided into nine parts, which include Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku,
Shikoku, Kyushu and Okinawa regions (as shown in Fig.1). The Automated Meteorological Data Acquisition System (AMeDAS) of Japan is observing meteorological data in about 1300 meteorological weather stations (Japan Meteorological Agency, 2013). The geographical coordinates of the 15 locations in this study are detailed in Table 1. Their locations are shown in Fig.1.

2.2. Rainfall data

Expanded AMeDAS (EA) weather data of 20 years (1981–2000) includes observed and calculated values at 1 hour intervals: air temperature, absolute humidity, wind speed, wind direction, normal direct solar radiation, horizontal diffuse solar radiation, precipitation, etc., for various locations in Japan. The maximum 1-hour rainfall event from each year was extracted for each location. A frequency analysis of these 20 data points at each location was implemented.

3. Methodology

3.1. Return period (T) analysis

The return period (T) (sometimes called the recurrence interval) is an estimation of the likelihood of an event such as flood or extreme precipitation to occur over an extended period of time, and is a means of expressing the exceedance probability (Mays, 2005).

T is a measure of the probable time interval between the occurrence of a given event and that of an equal or greater event. If a hydro meteorological variable (X) equal to or greater than x occurs on the average once in T years, then the probability of occurrence \( P(X \geq x) \) of such a variable is shown in the following Eq. (3-1):

\[
P = \frac{1}{T} (X \geq x) \quad \text{or} \quad T = \frac{1}{P} (X \geq x)
\]  

(3-1)

3.2. Plotting position

Plotting position refers to the probability value assigned to each piece of data to be plotted. Numerous methods have been proposed for the determination of plotting positions, most of which are empirical. Most plotting position formulas are represented by the following Eq. (3-2) (Chow et al., 1988),

\[
P = \frac{1}{T} = \left( m - b \right) / \left( n + 1 - 2b \right)
\]  

(3-2)

where \( m \) is the rank of a value in a list ordered by descending magnitude, \( n \) is the total number of values to be plotted, \( b \) is a parameter, which is different in different formulas (\( b = 0.5 \) for Hazen; \( b = 0.3 \) for Chegodayev; \( b = 0 \) for Weibull; \( b = 3/8 \) for Blom; \( b = 1/3 \) for Tukey; and \( b = 0.44 \) for Gringoten) (Chow, 1964).

We summarized the different formulas for plotting position in Table 2, using the above Eq. (3-2).

3.3. Probability distribution function (PDF) analysis

By fitting a distribution to a set of hydrologic data, a great deal of the probabilistic information in the sample can be compactly summarized in the function and its associated parameters. In the study, in order to find the best fit PDF for the annual maximum

Table 1

Geographical coordinates of 15 locations of the different regions of Japan.

<table>
<thead>
<tr>
<th>Region</th>
<th>Meteorological weather station</th>
<th>Latitude and longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hokkaido</td>
<td>Sapporo</td>
<td>43°03′ N, 141°21′ E</td>
</tr>
<tr>
<td></td>
<td>Souyamisaki</td>
<td>45°31′ N, 141°56′ E</td>
</tr>
<tr>
<td>Tohoku</td>
<td>Akita</td>
<td>39°43′ N, 140°05′ E</td>
</tr>
<tr>
<td></td>
<td>Aomori</td>
<td>40°49′ N, 140°46′ E</td>
</tr>
<tr>
<td>Kanto</td>
<td>Ogouchi</td>
<td>35°47′ N, 139°03′ E</td>
</tr>
<tr>
<td></td>
<td>Tokyo</td>
<td>35°41′ N, 139°45′ E</td>
</tr>
<tr>
<td>Chubu</td>
<td>Nagano</td>
<td>36°39′ N, 138°11′ E</td>
</tr>
<tr>
<td></td>
<td>Nagoya</td>
<td>35°10′ N, 136°57′ E</td>
</tr>
<tr>
<td>Kinki</td>
<td>Osaka</td>
<td>34°41′ N, 135°31′ E</td>
</tr>
<tr>
<td></td>
<td>Kyoto</td>
<td>35°01′ N, 135°43′ E</td>
</tr>
<tr>
<td>Chugoku &amp; Shikoku</td>
<td>Hiroshima</td>
<td>34°24′ N, 132°27′ E</td>
</tr>
<tr>
<td></td>
<td>Okayama</td>
<td>34°39′ N, 133°55′ E</td>
</tr>
<tr>
<td>Kyushu &amp; Okinawa</td>
<td>Fukuoka</td>
<td>33°35′ N, 130°22′ E</td>
</tr>
<tr>
<td></td>
<td>Kagoshima</td>
<td>31°33′ N, 130°32′ E</td>
</tr>
<tr>
<td></td>
<td>Naha</td>
<td>26°12′ N, 127°41′ E</td>
</tr>
</tbody>
</table>
hourly rainfall of Japan, we used and compared several PDFs, including Normal, LN, Gumbel, G2 and P3 distributions, which are commonly used for probability analysis of hydrology. A detailed description of these PDFs is shown in Table 3.

### 3.4. Frequency analysis using frequency factors

The formula expresses the frequency of occurrence of an event in terms of a frequency factor, $K_T$, which depends on the distribution of particular event investigated. Many frequency analyses can be described by the following formula (Chow, 1951),

$$ x_T = \mu + K_T \delta $$

where $x_T$ is the maximum value of an event corresponding to return period ($T$), $\mu$ is the mean of annual maximum hourly rainfall of observed years (here 20 years), $K_T$ is the frequency factor which depends upon the return period ($T$) and the assumed frequency distribution, $\delta$ is the standard deviation of annual maximum hourly rainfall of observed years (here 20 years).

The value of the parameter $z$ corresponding to an exceedance probability of $P (P = 1/T)$ can be calculated by finding the value of an intermediate variable $w$, as shown in the following formula,

$$ w = \sqrt{\ln \left( \frac{1}{P^2} \right)} $$

then calculating $z$ using the approximation,

$$ z = w - \frac{u_1}{u_2} $$

where

- $u_1 = 2.515517 + 0.802853 \cdot 0.010328 \cdot 23$
- $u_2 = 1 + 1.432788 \cdot 0.189269 \cdot 0.001308 \cdot 3$

### Table 3

<table>
<thead>
<tr>
<th>Distribution</th>
<th>Probability distribution function</th>
<th>Range</th>
<th>Equation for the parameters in terms of the sample moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>$f(x) = \frac{1}{\sqrt{2\pi\delta^2}} \exp\left(-\frac{(x-\mu)^2}{2\delta^2}\right)$</td>
<td>$-\infty \leq x \leq \infty$</td>
<td>$\mu$ = $\bar{x}$, $\delta$ = $s_x$</td>
</tr>
<tr>
<td>Log-Normal (LN)</td>
<td>$f(x) = \frac{1}{\delta x \sqrt{2\pi}} \exp\left(-\frac{(\ln x - \mu)^2}{2\delta^2}\right)$</td>
<td>$x &gt; 0$</td>
<td>$\mu_y$ = $\bar{y}$, $\delta_y$ = $s_y$</td>
</tr>
<tr>
<td></td>
<td>where $y = \ln x$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gumbel</td>
<td>$f(x) = \frac{1}{\alpha} \exp\left[-\frac{x-\mu}{\alpha} - \exp\left(-\frac{x-\mu}{\alpha}\right)\right]$</td>
<td>$-\infty \leq x \leq \infty$</td>
<td>$\alpha = \frac{\sqrt{6}\delta}{\pi}$, $\mu = \bar{y} - 0.5772\alpha$</td>
</tr>
<tr>
<td>Gamma2 (G2)</td>
<td>$f(x) = \frac{2^{1/\beta} \Gamma(\beta)}{\Gamma(\beta) \lambda^{1/\beta}} x^{(1-\beta)/\beta} \exp\left(-\frac{x^{1/\beta}}{\lambda}\right)$</td>
<td>$x \geq 0$</td>
<td>$\frac{\beta}{2} = \frac{1}{\lambda} \frac{1}{\Gamma(\beta)}$, $\lambda = \frac{\bar{x}}{\sqrt{\beta}}$</td>
</tr>
<tr>
<td></td>
<td>where $\Gamma$ = Gamma function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson type 3 (P3)</td>
<td>$f(x) = \frac{2^{1/\beta} \Gamma(\beta)}{\Gamma(\beta) \lambda^{1/\beta}} x^{(1-\beta)/\beta} \exp\left(-\frac{x^{1/\beta}}{\lambda}\right)$</td>
<td>$x \geq \epsilon$</td>
<td>$\lambda = \frac{\bar{x}}{\sqrt{\beta}}$, $\beta = \left(\frac{2}{C}\right)$, $\epsilon = \bar{x} - s_x \sqrt{\beta}$</td>
</tr>
</tbody>
</table>
when \( P > 0.5 \), \( 1 - P \) is substituted for \( P \) in Eq. (3-5), and the value of \( z \) computed by Eq. (3-6) is given a negative sign. The error in this formula is < 0.00045 in \( z \) (Abramowitz and Stegun, 1965). The frequency factors \((K_T)\) of various distributions are summarized and shown in the Table 4.

### 4. Results and discussion

#### 4.1. Return period \((T)\)

The return period \((T)\) in years of annual maximum hourly rainfall in the selected locations was computed using different formulas. The results are shown in Fig. 2.

The formula (Eq. (3-2)) for predicting the return period in years at all locations, of course have the same result for each data point (rainfall rank \( m \) from 1 to 20 in this case) along the x-axis but different rainfall amounts on the y-axis. Among the locations; Sapporo, Souyamisaki and Nagano are expected to have the most extreme events in the data of 30–50 mm per hour every 20–40 years depending on the formula used, 50–70 mm per hour every 20–40 years is expected for Akita, Aomori, Osaka, Kyoto, Hiroshima and Okayama, 70–90 mm per hour every 20–40 years is expected for Tokyo and Ogouchi, and over 90 mm per hour every 20–40 years is expected for Nagoya, Fukuoka, Kagoshima and Naha.

The analysis of return period \((T)\) indicates that there is a difference of up to 20 years (the same as the data set period) between various formulas for the highest ranked case \((m = 1)\), becoming 3.3 for \( m = 2 \) and smaller at smaller ranks. Among all the formulas, the use of Hazen’s formula gives the highest estimation of return period, followed by Gringorten, Cunnane, Blom, Tukey, Chegodayev, Weibull and California’s formulas in all the cases. It is necessary to select the formula that best predicts the return period \((T)\) of extreme event occurrence for hydraulic design.

#### 4.2. Probability distribution function \((PDF)\)

The probability distribution analysis of annual maximum hourly rainfall for the chosen locations is computed using various PDFs. Fig. 3 shows the probability distribution analysis of annual maximum hourly rainfall for representative locations (Sapporo, Akita, Tokyo, Nagoya, Osaka, Hiroshima and Fukuoka) of the different regions.

The result shows that the probability distributions of these distributions are different for each location. The annual maximum hourly rainfall at the maximum probability level is relatively higher in Kyushu & Okinawa (Fukuoka, Kagoshima and Naha) and Kanto (Ogouchi and Tokyo) regions, compared to the other regions.

Among these PDFs, one PDF is considered to be the best fit for each station. The analysis of best fit is carried out in the next chapter.

#### 4.3. Frequency distribution using frequency factors

Frequency factors of various distributions (detailed in Table 4) were used to predict the magnitudes of annual maximum hourly rainfall over a 20 year period. The observed value and the expected value which is calculated by various distributions are computed for the chosen locations. Fig. 4 shows the observed value and the expected value for representative locations (Sapporo, Akita, Tokyo, Nagoya, Osaka, Hiroshima and Fukuoka) of the different regions. Here, the probability levels for observed data are calculated by Eq. (3–1), assuming the return period \((T)\) given by the Weibull formula.

The result of analysis indicates that four different distributions (Normal, LN, LP3 and Gumbel) tend to have a low estimation at the extreme high values compared to observed values. Among four different distributions, the Normal distribution is the lowest estimation for all the locations.

### Table 4

Frequency factor \((K_T)\) of four different distributions.

<table>
<thead>
<tr>
<th>Distribution</th>
<th>Frequency factor ((K_T))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>( K_T = z )</td>
</tr>
<tr>
<td>Log-Normal (LN)</td>
<td>( K_T = z )</td>
</tr>
<tr>
<td></td>
<td>where ( y = \Phi + K_Ny ), ( y = \log x )</td>
</tr>
<tr>
<td>Log-Pearson type3 (LP3)</td>
<td>( K_T = z + (z^2 - 1)k + \frac{1}{3}(z^2 - 6z)k^2 - (z^2 - 1)k^3 + \frac{z^4}{3}k^4 + \frac{1}{3}k^3 )</td>
</tr>
<tr>
<td></td>
<td>where ( k = C_k/6 )</td>
</tr>
<tr>
<td></td>
<td>( C_k ) is coefficient of skewness of ( y )</td>
</tr>
<tr>
<td>Gumbel</td>
<td>( K_T = -\frac{\sqrt{6}}{\pi} \left{ 0.5772 + \ln \left[ \ln \left( \frac{T}{T - 1} \right) \right] \right} )</td>
</tr>
<tr>
<td></td>
<td>where ( T ) is the return period in years</td>
</tr>
</tbody>
</table>
Fig. 2. Return period in years computed using eight different formulas for 15 locations in nine regions of Japan.
Fig. 2. (continued)
5. Determination of the best fit PDF

For the purpose of prediction, it is usually required to understand the shape of underlying distribution of the population. In order to determine the underlying distribution, it is a common practice to fit the observed distribution to a theoretical distribution such as Normal distribution mentioned above. This is done by comparing the observed frequency in the data to the expected frequency of the theoretical distribution since certain types of variables follow specific distribution (Tilahun, 2006).

One of the most commonly used tests for testing frequency distribution is the Chi-square ($\chi^2$) test (Haan, 1977). The test compares the actual number of observations (expected values are calculated based on the distribution under consideration) that fall in the class intervals. The $\chi^2$ test is computed from the following Eq. (5-1)-Eq. (5-3),

$$
\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}
$$

(5-1)

Fig. 3. Probability distribution analysis of annual maximum hourly rainfall for representative locations of the different regions using various.
where $Q_i$ is the observed annual maximum hourly rainfall, $E_i$ is the expected annual maximum hourly rainfall calculated by various distributions, $i$ is the number of observations (1, 2, ……, $k$), $F$ is the cumulative density function (CDF) of the probability distribution being tested, and $n$ is the sample size.

In this study, the $\chi^2$ test is used to find the best fit PDF for the selected locations. Here, we calculated and found the best fit PDF for the selected main locations and showed the result in Table 5.

It showed that among the selected locations, 14 locations are best fitted by LP3 distribution, and only one location (Souyamisaki in Hokkaido region) is best fitted by LN distribution (only slightly better than the LP3 distribution). The second-best fit distribution is about evenly divided between LN and Gumbel across all remaining cases. Thus, we can conclude that the LP3 distribution may be the best fit PDF for predicting the annual maximum hourly rainfall at most of observed stations in Japan.
6. Conclusions and future work

In this study, based on the EA weather data of Japan from 1981 to 2000 (20 years), we implemented frequency analysis of annual maximum hourly rainfall for 15 locations in the nine regions of Japan, using eight different formulas for predicting the return period and five different PDFs for modeling the probability distribution. Furthermore, the analysis of best fit PDF was also carried out by $\chi^2$ test for annual maximum hourly rainfall for chosen locations in Japan.

By return period analysis, the return period expected by eight different formulas differs by a range up to the length of the data period (in this case 20 years) for the highest ranked rainfall event. This difference becomes much smaller with each successively lower rank (3.3 years difference for the second rank, and so on). Among all the formulas, the use of Hazen’s formula gives the highest estimation of return period, and the California formula gives the lowest.

By frequency analysis using frequency factors, the result indicates that four different distributions used in this contribution have a relatively lower estimation of extremely high values than the observed value. Among these distributions, as expected the Normal distribution is the lowest estimation for all the chosen locations.

By the analysis of best fit PDF, we can see that the LP3 distribution is best fit for 14 of the 15 chosen locations, except for one location (Souyamisaki of the Hokkaido region) in which case the LN distribution is only slightly better than the LP3 distribution. The second-best fit distribution is about evenly divided between LN and Gumbel across all remaining cases. Thus, it is considered that LP3 distribution may be the best fit PDF for predicting the probability of annual maximum hourly rainfall at most observed locations in Japan through $\chi^2$ test. It will contribute to the prediction of the annual maximum hourly rainfall, drainage works and drainage structures for locations of Japan in the future.

It can be noted that the values for the $\chi^2$ test tend to be much larger (worse fit) when there is a larger difference between the highest maximum rainfall and the second-highest at each location. Aomori has a maximum hourly rainfall of 64 mm and a second-highest of 27 mm making it the largest difference among the chosen locations. It also has the largest $\chi^2$ test values for each type of distribution. Similarly, Kagoshima has the second largest difference, while Nagoya and Fukuoka have the third largest differences, and also have some of the largest $\chi^2$ test values in these results. This suggests that extreme outliers in hourly maximum rainfall strongly affected the curve-fitting or that the timing of the heavy rainfall events relative to the measurement period needs more examination.

The further research will focus on the frequency analysis of annual maximum precipitation with consecutive-hour or consecutive-day for locations of Japan. Furthermore, more recent periods, i.e., from 2000 to 2015, should be added as an extended dataset and analyzed to test the validity for a longer period.

Disclosure statement

The authors declare that there is no conflict of interests regarding the publication of this paper.

References


Table 5

Chi-square ($\chi^2$) values for four different distributions in 15 locations with best fit.

<table>
<thead>
<tr>
<th>Location</th>
<th>Normal</th>
<th>LN</th>
<th>LP3</th>
<th>Gumbel</th>
<th>Best fit PDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sapporo</td>
<td>8.52</td>
<td>1.19</td>
<td>1.09</td>
<td>1.18</td>
<td>LP3</td>
</tr>
<tr>
<td>Souyamisaki</td>
<td>23.3</td>
<td>3.32</td>
<td>3.37</td>
<td>4.02</td>
<td>LN</td>
</tr>
<tr>
<td>Akita</td>
<td>23.0</td>
<td>4.87</td>
<td>4.18</td>
<td>4.79</td>
<td>LP3</td>
</tr>
<tr>
<td>Aomori</td>
<td>133</td>
<td>32.5</td>
<td>18.7</td>
<td>45.3</td>
<td>LP3</td>
</tr>
<tr>
<td>Tokyo</td>
<td>30.3</td>
<td>3.22</td>
<td>3.16</td>
<td>3.58</td>
<td>LP3</td>
</tr>
<tr>
<td>Ogouchi</td>
<td>21.8</td>
<td>4.04</td>
<td>3.58</td>
<td>5.26</td>
<td>LP3</td>
</tr>
<tr>
<td>Nagano</td>
<td>15.1</td>
<td>3.25</td>
<td>2.53</td>
<td>4.14</td>
<td>LP3</td>
</tr>
<tr>
<td>Nagoya</td>
<td>42.3</td>
<td>6.02</td>
<td>5.30</td>
<td>6.34</td>
<td>LP3</td>
</tr>
<tr>
<td>Osaka</td>
<td>17.8</td>
<td>4.24</td>
<td>2.93</td>
<td>3.35</td>
<td>LP3</td>
</tr>
<tr>
<td>Kyoto</td>
<td>17.8</td>
<td>1.85</td>
<td>1.66</td>
<td>2.97</td>
<td>LP3</td>
</tr>
<tr>
<td>Hiroshima</td>
<td>11.8</td>
<td>3.54</td>
<td>2.24</td>
<td>2.60</td>
<td>LP3</td>
</tr>
<tr>
<td>Okayama</td>
<td>25.6</td>
<td>8.95</td>
<td>5.66</td>
<td>7.40</td>
<td>LP3</td>
</tr>
<tr>
<td>Fukuoka</td>
<td>41.9</td>
<td>13.6</td>
<td>9.61</td>
<td>11.9</td>
<td>LP3</td>
</tr>
<tr>
<td>Kagoshima</td>
<td>30.1</td>
<td>8.09</td>
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