Developing an Interval Forecasting Method to Predict Undulated Demand

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Abstract

This study provides a flexible and mathematically precise method for forecasting tourism demand from all five continents of the globe to Taiwan and with potential to assist tourism operators and government officials in improving their management planning and strategy. This investigation applied the Grey Envelop Prediction Model (GEPM) to predict international passenger arrivals to Taiwan. The analysis result shows monthly, seasonal and annual predictions. The prediction values of international tourist numbers can answer the practical needs of managers, owners, and government departments and help in operational and management strategy development. The contributions of this study is provides an effective method for forecasting number of international visitors, and the result provided the flexible, accurate, and efficient interval predicted values used by researchers, mangers and administrators for developing manpower, finance, marketing, and administrative decision-making schemes.
Keywords: Grey Envelop Prediction Model (GEPM); Demand forecasting; Seasonality; Tourism demands

1. Introduction

Management judgment is widely used to adjust statistical forecasts in order to take into account special events. This shows forecasting methodology is most relevant and easily applicable in the field of management, moreover, the key objectives of management is demand forecasting (Lee, Lee and Kim, 2008; Hilas, Goudos and Sahalos, 2006; Lee et al., 2006). Currently, to improve national economic development countries around the world are actively promoting tourism. Countries thus wish to better understand their international visitors and tourism revenues, to help rapidly formulate appropriate tourism policies. Furthermore, the tourism industry is characterized by variability, creating a need for accurate short and long term tourism demand forecasts. Tourism demand forecasting has attracted increased attention during the past decade. Investigations of this area have concluded that econometric models can help policymakers establish appropriate economic strategies to stimulate tourism demand and generate accurate demand forecasts.

While international visitor demand strongly influences administrative decision-making in tourism, predicting demand remains extremely challenging. Tourism demand forecasting is especially important for decision making for long term forecasts related to investment in aircraft, hotels and infrastructure. Governments are interested total inbound and outbound tourist numbers and associated expenditures, while hotel operators are interested in demand at the city and regional levels (Witt and Witt, 1995). This study suggested a predict method for improving the accuracy of tourist numbers in Taiwan.
Modeling of international tourism demand has attracted numerous empirical studies since the 1950s. Numerous studies have compared methods for forecasting tourism demand. As one of the pioneers in this field, Fritz, Brandon and Xander (1984) and Sheldon and Var (1985) provided a considerably more comprehensive examination of the problem than any previous study. In contrast, a broader review of tourism forecasting by Crouch (1995) integrated the empirical findings of 80 studies of international tourism demand and discussed their application. Recently, researchers have preferred to combine multiple methods of forecasting tourism demand. The prediction method of the combining type may improve the prediction ability, but also increases the model complexity. Wong et al. (2007) examined whether combining the tourism forecasts generated from different models can enhance forecasting accuracy. Oh and Morzuch (2005) obtained results supported the conclusion that one forecasting model outperforms the others in terms of a single performance statistic. Moreover, Song and Li (2007) reviewed the published studies on tourism demand modeling and forecasting since 2000.

In practice, previous studies on tourism demand suffer complex conceptual and methodological problems, thus casting doubt on their validity and interpretability. The methods available for forecasting tourism demand are limited. Most studies dealing with tourism demand forecasting are econometric. However, spatial models and time-sequence models have also been applied to tourism demand forecasting (Witt and Witt, 1995; Riddington, 1999). ARIMA forecasting being superior (Wong et al., 2007; Oh and Morzuch, 2005; Preez and Witt, 2003), but has not been fully amplified by other researchers. Time-sequence models can frequently achieve good forecasting results (Burger et al., 2001). In comparison, regression models (also known as econometric models) identify the independent variables that could significantly
influence the values of a dependent variable and then model the relationship of the
dependent and independent variables; furthermore, Li et al. (2006) developed time
varying parameter (TVP) linear and nearly ideal demand system (LAIDS) models in
both long-run (LR) static and short-run error correction (EC) forms.

Previous studies on tourism demand forecasting often deal with multiple
forecasting methods (Song and Li, 2007; Triantafyllopoulos, 2007), but applying the
analytical methods presented above is complex and challenging (Wong et al., 2007).
Particularly, tourism demand revealed a clear on-season and off-season in Taiwan.
Moreover, Lee et al., (2008) pointed out some choice-based diffusion models have
suffered from some limitations in their endeavor to forecast demand for new
technologies because they have usually depended on historical sales data or adopter
data, and thus explaining the diffusion of newly introduced technology with a limited
number of data observations is difficult. Thus the purpose of this study is developing
an easy and accurate method to predict international tourist arriving to Taiwan. This
study suggests applying the Grey Envelop Prediction Model (GEPM) to predict
international passenger numbers. This work extended Lin and Yang (Lin and Yang,
2004) use of the grey forecasting model (GM) to forecast the output value of the
Taiwanese IC industry in order to develop an interval forecasting method for
predicting tourism demand in Taiwan. Moreover, Lin and Yang (2004) modified GM
from Lin and Yang (2003) applies the GM to forecast accurately the output value of
Taiwan's optoelectronics industry. Wang and Lin (2007) applied a Grey model to
predict the annual quantity of demand for imported consumer goods. Furthermore,
Hsu (2003) indicated that the GM is better suited to short-term predictions than to
mid- and long-term predictions.

The GM provide only one prediction value, but the GEPM algorithm also
provides an effective method of accurately predicting individual events that occur within a specific time scale (Lee et al., 2007), and can deal with and fluctuate the obvious advantages associated with materials array (Xiao and Ma, 2005). Furthermore, GEPM is designed to identify the ranges of variation of the forecast values, which then serve as boundary values in the tourist arrival reduction model. GEPM provides a better method for a goal programming model to determine the boundary values of the constraints, and thus provides elasticity and effective forecasting for solving the problem, making it difficult to estimate seasonal variation in international traveler numbers. In this regard, this study applied GEPM to forecast future overseas passenger arrivals in Taiwan during specific periods.

This study presents a flexible and mathematically precise method for forecasting international visitor numbers and improving management planning and strategy development for tourism industry owners and government officials. This information is expected to help tourism industry proprietors and managers in better meeting their human resources needs, as well as in financial control, marketing planning, and cost control. Furthermore, it is expected that the techniques presented here will prove useful in other service industries wishing to better understand their seasonal demand.

2. Analysis Methods

Deng (2002) in 1982 first proposed the concept of grey system theory. Problems involving uncertainty are commonplace in nature. Amount samples can be solved by probability and statistics ways. Another form of uncertainty also exists, namely uncertainty involving small-scale data, incomplete information and a lack of experience, and this form of uncertainty is also suitable for dealing with via grey system theory.
The Grey forecasting model (GM) is the core of Grey system theory. The Grey system theory treats all variables as a Grey quantity within a certain range. GM then collects available data to obtain the internal regularity. The model examines the nature of internal regularity in managing the disorganized primitive data. The model was established by transferring the arranged sequence into a differential equation.

2.1 Grey envelopment Predictions Model (GEPM)

Figure 1 presents the procedure of applying GEPM to forecasted tourism demand to Taiwan. Moreover, Figure 2 shows the combination of GEPM and is composed of upper, original data sequence and lower curves. Upper envelopment line was based on the curve of original data sequence and connects peak-point to draw the curve. Lower envelopment line was based on the curve of original data sequence connects valley-point to draw the curve. GEPM differs from GM (1, 1) in terms of interval estimation prediction value (Deng, 2002). Furthermore, GEPM involves: (1) extending the upper and lower envelopment curve and obtaining behavioral variable variation in the prediction interval, (2) upper and lower envelopment curve enveloping in original non-negative data sequence, recognizing predicted values in envelopment intervals and abandoning predicted values exceed the envelopment interval, (3) establishing the GM (1, 1) model based on the central value of envelopment line and obtaining the whiteness differential equation for future prediction.

Insert ** Figure 1. The procedure of GEPM to forecast tourism demand

Assume that \( x = \{x(1), x(2), \ldots, x(k) | k \geq 4 \} \) is the original non-negative data
sequence, taken consecutively and at equal time intervals. The procedures for applying the GEPM to forecast future values comprise the following six steps:

**Step 1. Drawing upper and lower envelopment lines for** \( x \)

Based on the original data sequence \( x \) draws the contour of upper envelopment curve \( x_u \) and lower envelopment curve \( x_l \) in Figure 2. The upper and lower envelopment tendency values indicate the “long-term” interval predicted values. Seasonally tendency values refer to the “medium-term” interval predicted values. Finally, the monthly forecasting values refer to the “short-term” predicted values.

*Insert **Figure 2.** Contour of upper and lower envelopment curve*

**Step 2. Create an upper and lower envelopment curve data sequence**

To create data sequence of upper and lower envelopment curve at an equal time interval where the sequence includes \( x_u \) and \( x_l \) but not all vertexes. The upper envelopment data sequence \( x_u \) and lower envelopment data sequence \( x_l \) are shown below:

\[
x_u = (x_u(1_u), x_u(2_u), \ldots, x_u(i_u)), i = 1, 2, \ldots, m, \quad (1)
\]
\[
= (x_u(1), x_u(2), \ldots, x_u(n)), \quad \text{is } x_u \text{ corresponding } x.
\]

\[
x_l = (x_l(1_l), x_l(2_l), \ldots, x_l(i_l)), i = 1, 2, \ldots, m, \quad (2)
\]
\[
= (x_l(1), x_l(2), \ldots, x_l(n)), \quad \text{is } x_l \text{ corresponding } x.
\]

**Step 3. Establish the GM (1, 1) based on upper and lower envelopment for future predicted values**

Establish the GM (1, 1) for upper and lower envelopment for future predicted
values and calculate the relative errors for GEPM, then the predicted values $x_u$ and $x_z$ from AGO as:

$$\text{GM}_p:\ \left\{\begin{array}{l}
\text{AGO: } x_u \rightarrow x_u^{(0)} = \left(\sum_{k=1}^{1} x_u^{(0)}(k), \sum_{k=2}^{2} x_u^{(0)}(k), \cdots, \sum_{k=m}^{m} x_u^{(0)}(k)\right) \\
\text{AGO: } x_z \rightarrow x_z^{(0)} = \left(\sum_{k=1}^{1} x_z^{(0)}(k), \sum_{k=2}^{2} x_z^{(0)}(k), \cdots, \sum_{k=m}^{m} x_z^{(0)}(k)\right)
\end{array}\right. \tag{3}$$

$$\text{GM}_w:\ \left\{\begin{array}{l}
\text{AGO: } x_u \rightarrow x_u^{(0)}(k+1) = \left(x_u(1) - \frac{b}{a}\right)e^{-ak} + \frac{b}{a} \\
\text{AGO: } x_u^{(0)}(k+1) = x_u^{(0)}(k) + x_u^{(0)}(k) \\
\text{AGO: } x_z^{(0)}(k+1) = x_z^{(0)}(1) - \frac{b}{a}e^{-ak} + \frac{b}{a} \\
\text{AGO: } x_z^{(0)}(k+1) = x_z^{(0)}(k) - x_z^{(0)}(k)
\end{array}\right. \tag{5}$$

Step 4. Establish the GM (1, 1) based on the original data sequence for future forecast values

To obtain the values predicted based on the original data sequence from AGO, as follows:

$$\text{GM}_p \circ \text{AGO: } x \rightarrow x^{(0)} = \left(\sum_{k=1}^{1} x^{(0)}(k), \sum_{k=2}^{2} x^{(0)}(k), \cdots, \sum_{k=m}^{m} x^{(0)}(k)\right) \tag{9}$$

$$\text{GM}_w \circ \text{AGO: } x \rightarrow x^{(0)}(k+1) = \left(x(1) - \frac{b}{a}\right)e^{-ak} + \frac{b}{a} \tag{10}$$

Step 5. Create and forecast the central sequence of the envelopment region

Let $x_c$ denote the central sequence of envelopment and establish GM (1, 1) as:
\[ x_a = (x_a(1), x_a(2), \ldots, x_a(m_a)) \]

\[ = (x_a(1), x_a(2), \ldots, x_a(m)) \]

\[ = (0.5(x_a(1) + x_a(1)), \ldots, (0.5(x_a(m) + x_a(m))) \] (11)

\[ \text{GM}_p \circ \text{AGO}: \quad x_a \rightarrow x_a^{(0)} = (\sum_{k=1}^{1} x_a^{(0)}(k), \sum_{k=1}^{2} x_a^{(0)}(k), \ldots, \sum_{k=1}^{m} x_a^{(0)}(k)) \] (12)

\[ \text{GM}_W \circ \text{AGO}: \quad x_a^{(0)}(k+1) = (x_a^{(0)}(1) - \frac{b}{a})e^{-ak} + \frac{b}{a} \] (13)

\[ x_a^{(0)}(k+1) = x_a^{(0)}(k+1) - x_a^{(0)}(k) \] (14)

Step 6. Evaluate and discuss accuracy and the result of prediction

Discuss whether the predicted values fall within or outside of the envelopment region.

2.2 Data Source

This study forecasts international tourist arrivals to Taiwan using the Grey Envelop Prediction model. The study data comprised secondary data obtained from the Taiwan Tourism Bureau of the Ministry of Transportation and Communication, R.O.C. (Tourism Bureau, M.O.T.C.) The Monthly Statistics on Tourism Report. Consequently, this study applied the statistics source that based on number of overseas visitor arrivals and is computed by the nationality to forecasting international tourist arrivals to Taiwan. The Monthly Tourism Statistics Report is a monthly statistical report issued by the Tourism Bureau, M.O.T.C., international visitors are defined in the report as all visitors arriving in Taiwan from overseas, with the
statistical analysis also includes purpose of visit, with categories including business, pleasure, visiting relatives of friends, attending conferences, and study. The analysis presented in this study is based on data covering the period from Jan. 2006 through Aug. 2007. Table 1 lists the original non-negative data sequence for the five continents.

**Table 1** International visitors broken down by continent

3. Results

3.1 Drawing upper and lower envelopment line and creating data sequence

The broken-line graph displays the original data sequence by continent, and draws upper and lower envelopment lines connecting crest and trough value. Generally, Upper envelopment curve and lower envelopment curve are drawn based on past experience. This study draws the upper and lower envelopment curves. First, tourist visitor numbers to Taiwan during the on- and off- seasons in are displayed by month for each continent. To use GM (1, 1) prediction on- and off-season values of tourist during 2008 and 2009. Then, to draw $x_1$ and $x_{-1}$ that include values of prediction during 2008 and 2009. Finally, data sequences are estimated based on the upper and lower envelopment curves. For example, based on past data Asian visitors to Taiwan peak every year in March and are lowest in July. The numbers of Asian visitors traveling to Taiwan during March and July in the years 2004 through 2007 are listed below:

$x_{Mar.}=(x_{Mar.}(2004), x_{Mar.}(2005), x_{Mar.}(2006), x_{Mar.}(2007))$

=\( (130,700,\ 173,400,\ 186,570,\ 210,610) \)

$x_{Jul.}=(x_{Jul.}(2004), x_{Jul.}(2005), x_{Jul.}(2006), x_{Jul.}(2007))$
\[ \text{GM (1, 1) predicts the following values for March and July of 2008 and 2009:} \]

\[ x_{\text{Mar.}} = (x_{\text{Mar.}}(2008), x_{\text{Mar.}}(2009)) = (245,880, 283,020) \]

\[ x_{\text{Jul.}} = (x_{\text{Jul.}}(2008), x_{\text{Jul.}}(2009)) = (154,680, 160,170) \]

\[ x_0 \text{ and } x_1 \text{ predictions for 2006, 2007 and 2008 are illustrated in Figure 2.} \]

3.2 Predict tourism demand in Taiwan

Table 2 lists the results for three monthly interval values, central line values, original sequence prediction values and prediction accuracy rate. GM (1, 1) prediction values of the original sequence decrease in the interval region. The forecasting accuracy of the tourism demand in Taiwan envelop interval exceeds 99%. Figure 3 reveals that Asian passengers arrival to Taiwan is expected to stay in a mildly increasing trend, namely Asian tourism demand to Taiwan was either very strong or average. Table 3 exhibits the forecasting tendency of tourism demand from all five continents of the globe to Taiwan. Figure 4 reveals that European passengers demand is seen as modestly good, that is, European tourism demand to Taiwan appears to grow steadily. Figure 5 illustrates that American tourism demand to Taiwan exhibits a steady development pattern. Figure 6 shows that passengers from Oceanian predicted using the grey envelop model exhibit an upwards scattered growth tendency. Figure 7 reveals that passenger numbers from Africa as predicted using the grey envelop method exhibit a decreasing tendency. As economic condition improves, the level of overseas tourism demand to Taiwan continued to follow an upward trajectory and was predominantly driven by Asian, European and Oceanian.

**Table 2** Comparison of GM and GEPM accuracy in tourism demand
4. Conclusions

This study applied GEPM to forecast overseas passenger numbers, could lead to more accurate forecasts of the effects of administrative decision-making schemes. The contributions of this investigation lie in providing an effective method for forecasting international visitor numbers, and the result provided the flexible, accurate, and efficient interval predicted values used by researchers, mangers and administrators for developing manpower, finance, marketing, and administrative decision-making schemes.

Moreover, this study designated that the upper and lower envelop tendency values refer to the “long-term” interval predicted values that can be provided to government officer to develop tourism industry policy and strategies; and further, the seasonally tendency values refer to the “medium-term” interval predict values that can
be provided to tourism operators to make operational and management decision. Furthermore, the monthly forecasting value refers to “short-term” predict values used by tourism industry department managers to make short-term workforce, administrative expense, achievement, and accounting decisions. Most importantly, the upper and lower envelop curves provide a development tendency reference to managers and administrators in decision-making, for instance, the continents (Asia and Oceania) of scattered growth tendency whom can set up attractive image by media, moreover, fits the tourists needs to the products.

Furthermore, GEPM produces the interval predicted values of upper, middle, and lower envelop curve at equal time interval predicted values. Furthermore, GEPM algorithm provides an effective method to deal with single events that occur in some specific time scale. The most significant advantage of GEPM is that it provides more effective method of problem forecasting, creating difficulties in estimating variation in international visitor numbers based on intervals during the on and off seasons. The changeable nature of tourism demand is a challenging problem for managers and policymakers. In this connection, this study presents a new method for enveloped the interval area for overseas passenger numbers to Taiwan.

This work differentiates seasonal of interval area upon the observed of researchers and managers, and then predicted the upper and lower envelop values; besides link the adjacent values and shaping the upper and lower curves. The analytical results indicate that administrators can refer to middle to upper curve interval prediction values in the busy season, and lower to middle curve interval prediction values in the slack season in their planning and decision making. Namely, the proposed method is suitable for predict the changeable nature of tourism demand, as well as being simply to use. Furthermore, the predictions obtained using the model
can assist managers and administrators in making manpower, finance, marketing, and administrative decisions. Finally, this investigation develops a new method for tourism demand forecasting.

References


Figure 1. The procedure of GEPM to forecast tourism demand.
Figure 2. Contour of upper and lower envelopment curve.

Note: k = year; x = number of international visitors
Figure 3. Grey envelopment prediction of tourist arrivals to Taiwan from Asia.
Figure 4. Grey envelopment prediction of tourist arrivals to Taiwan from Europe.
Figure 5. Grey envelopment prediction of tourist arrivals to Taiwan from America.
Figure 6. Grey envelopment prediction of tourist arrivals to Taiwan from Oceania.
Figure 7. Grey envelopment prediction of tourist arrivals to Taiwan from Africa.
Table 1

International visitors broken down by continent

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Asia</th>
<th>America</th>
<th>Europe</th>
<th>Oceania</th>
<th>Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>Jan</td>
<td>152,140</td>
<td>41,030</td>
<td>17,360</td>
<td>5,980</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>Feb</td>
<td>177,180</td>
<td>34,460</td>
<td>16,880</td>
<td>4,670</td>
<td>990</td>
</tr>
<tr>
<td></td>
<td>Mar</td>
<td>186,570</td>
<td>42,650</td>
<td>22,130</td>
<td>5,240</td>
<td>870</td>
</tr>
<tr>
<td></td>
<td>Apr</td>
<td>158,840</td>
<td>42,200</td>
<td>19,930</td>
<td>5,480</td>
<td>870</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>163,180</td>
<td>41,170</td>
<td>17,870</td>
<td>4,450</td>
<td>735</td>
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<tr>
<td></td>
<td>Jun</td>
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<td>48,820</td>
<td>19,500</td>
<td>5,400</td>
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<tr>
<td></td>
<td>Jul</td>
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<td>39,600</td>
<td>18,400</td>
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<td>181,050</td>
<td>43,770</td>
<td>21,610</td>
<td>5,500</td>
<td>880</td>
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<tr>
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<td>Nov</td>
<td>193,510</td>
<td>44,260</td>
<td>22,450</td>
<td>5,890</td>
<td>710</td>
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<td>Dec</td>
<td>190,390</td>
<td>47,950</td>
<td>17,170</td>
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<td>2007</td>
<td>Jan</td>
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<td>36,280</td>
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<td>590</td>
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<td>40,850</td>
<td>19,870</td>
<td>5,900</td>
<td>820</td>
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### Table 2

Comparison of GM and GEPM accuracy in tourism demand forecasting

<table>
<thead>
<tr>
<th>Continents</th>
<th>Prediction value</th>
<th>25 (Jan)</th>
<th>26 (Feb)</th>
<th>27 (Mar)</th>
<th>Accuracy</th>
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<td>Asia</td>
<td>Prediction value</td>
<td>172,260</td>
<td>172,370</td>
<td>172,500</td>
<td>92.9%</td>
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<td></td>
<td>Prediction interval</td>
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<td>[151,935, 246,750]</td>
<td>[152,330, 252,440]</td>
<td>[99.5%, 99.4%]</td>
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<tr>
<td></td>
<td>median</td>
<td>196,000</td>
<td>197,500</td>
<td>199,100</td>
<td>99.5%</td>
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<td>Europe</td>
<td>Prediction value</td>
<td>20,500</td>
<td>20,600</td>
<td>20,700</td>
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<tr>
<td></td>
<td>Prediction interval</td>
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<td>[15,750, 26,475]</td>
<td>[15,630, 26,300]</td>
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<td>median</td>
<td>20,950</td>
<td>21,025</td>
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<td>America</td>
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<td>44,580</td>
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<td>Prediction interval</td>
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<td>[33,740, 49,670]</td>
<td>[33,750, 49,730]</td>
<td>[99.6%, 99.5%]</td>
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<td>41,610</td>
<td>41,640</td>
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<td>[5,200, 7,000]</td>
<td>[99.2%, 97.4%]</td>
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<td>6,085</td>
<td>6,100</td>
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<td>[520, 905]</td>
<td>[515, 900]</td>
<td>[99.2%, 99.6%]</td>
</tr>
<tr>
<td></td>
<td>median</td>
<td>715</td>
<td>710</td>
<td>705</td>
<td>99.5%</td>
</tr>
</tbody>
</table>