Supplementary information

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Monte Carlo simulation application for the simulation of tanker truck and bottled water flow rates

This section explains the application of Monte Carlo simulation in estimating the flow rates of bottled water and water transported by tanker trucks. The provision of water to the population through these means is a common occurrence in Mexican cities. However, there is no official information available regarding its volume, so it is relevant to approximate its volume using the Monte Carlo method, and secondly, it is important to know these flows because they reveal information related to the human right to water in terms of sufficiency, acceptability and affordability.

The lack of official documentation on the flow rates of bottled water and water transported in tanker trucks prompted us to devise a method for estimation based on the city residents' consumption patterns. To achieve this objective, we created a 30-question survey that dealt with various aspects of water in households. Out of these, only six questions were used to estimate the aforementioned flow rates. The survey was conducted using the Google Forms platform, which allowed us to overcome the challenges posed by the COVID-19 sanitary measures implemented in Puebla in 2021. The survey link can be found here:

(https://docs.google.com/forms/d/e/1FAIpQLSfRlOKB6i5WSg9Rxiv-K_CYPfPpDkDLFHUyyoROgTalhSAs5Q/viewform?usp=sf_link).

The survey was conducted through the utilization of the snowball method, a non-probabilistic approach. While we acknowledge that a probabilistic approach would be superior, it was the only feasible option given the context and the limited resources for the study. At the end of the document, two sets of data from the Monte Carlo simulation are compared with information from the official census to validate the process.

The flow estimated in the model for the city of Puebla is 1.52% of all the water estimated in the MHU of the study area and 6.08% when only considering the flow used in the central city.

General survey data

The data collected from the survey were processed according to the postulates and assumptions outlined in the methodology section of the article. The responses were converted to quantifiable variables to conduct statistical analysis and obtain their probability distributions.

Figure S1. *Number of surveys applied per neighborhood in the city of Puebla.*

Source: Own elaboration.

In the following sections, the numbering of the equations corresponds to those presented in the methodology section of the article.

Estimation of water flow rates transported by tanker truck.

Equations S1 and S2 were utilized to calculate the water flow ratios transported by tanker trucks within the city.

$$Q_{tanker-t,\text{cis}} = Ac * Pc * Rc * Mcp * V/10^9 \tag{S1}$$

$$Q_{tanker-t,\text{wt}} = At * Pt * Rt * Mtp * V/10^9 \tag{S2}$$

We simulated the terms of the equation that refer to the water storage capacity of the dwellings (*Ac, At*), the number of tankers that supply water to the dwellings per year (*Pc, Pt*), the ratio of dwellings that have a cistern to those that have only a water tank (*Rc, Rt*), the ratio of dwellings that require tankers to supply water (*Mcp, Mtp*). And the total number of homes is a known quantity (*V*), which is then divided by 10 to the 9th power to convert the units from liters per year to cubic hectometers per year.

Definition of assumptions for Monte Carlo simulation (water transported by tanker trucks)

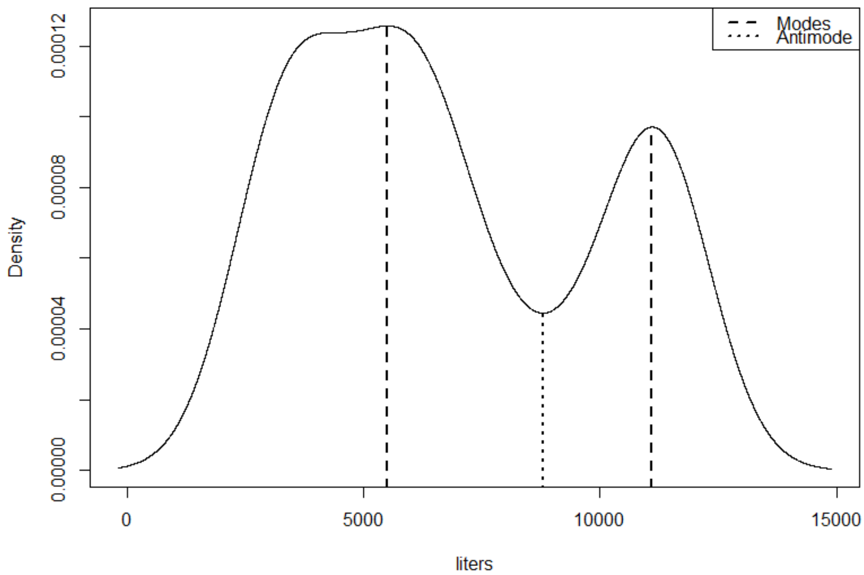
We establish the initial assumptions for the Monte Carlo simulation of the variables mentioned in equations S1 and S2.

Proposed probability distribution for simulating water storage capacity in a dwelling with cistern (Ac).

The summary statistics and probability density derived from the survey data and its associated probability density information are displayed below.

```
Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
   3100    4100    6100    6817   10850   11600       3
```

Figure S2. *Probability density plot of water storage capacity in dwelling with cistern.*



Source: Own elaboration.

```
Estimated probability of distribution information
Estimated location
Modes: 5498.015  11100.23
Antimode: 8787.722
```

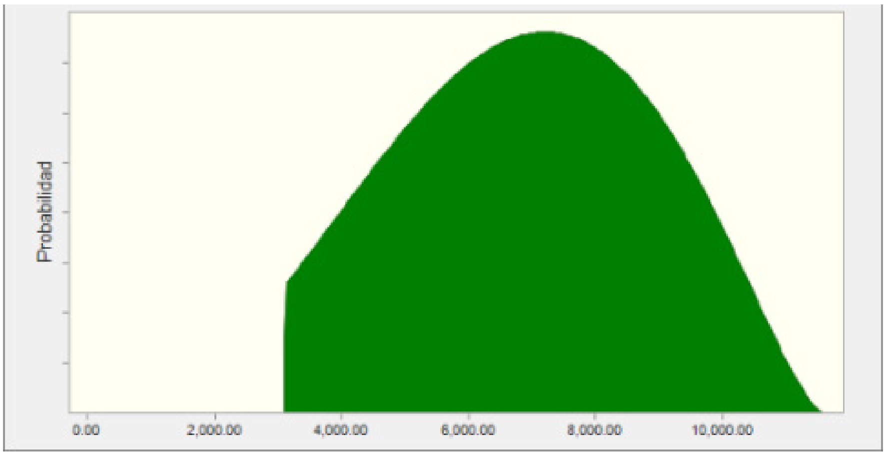
```
Estimated value of the density
Modes: 0.0001256329  9.708504e-05
Antimode: 4.447977e-05

Critical bandwidth: 1097.065
```

Because the distribution exhibits two modes, a compound rule of three was utilized to assign a single value for the mode in the distribution, yielding 7203.476195 liters.

The estimated parameters were then entered into a Beta PERT probability distribution.

```
Beta PERT distribution with the parameters:
        Minimum                       0.00
        More probable                 7,203.48
        Maximum                       11,600.00

        The selected range was 3,100.00 to ∞
```

Figure S3. *Proposed probability distribution for water storage capacity in dwelling with cistern.*



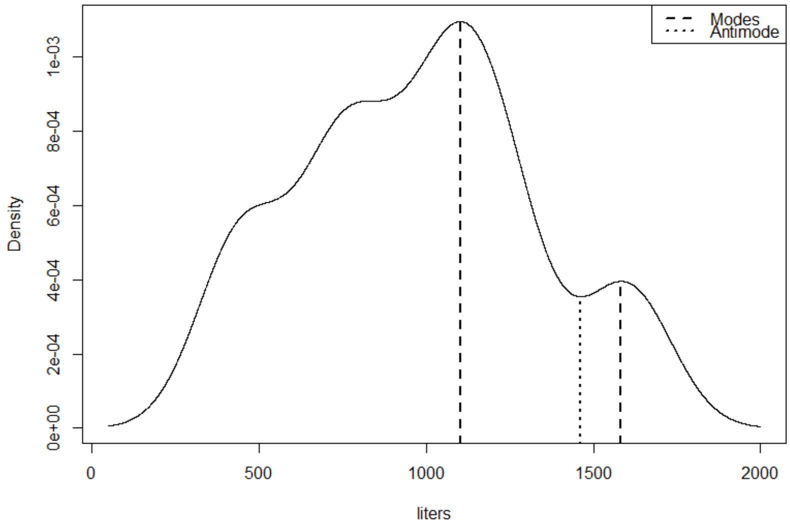
Source: Own elaboration.

Proposed probability distribution for the simulation of water storage capacity in dwellings without a cistern, with a water storage tank (At).

Summary statistics and probability density calculated from the data collected in the survey.

```
Summary of statistical parameters
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's 
  450.0   750.0   950.0   975.9  1250.0  1600.0       3 
```

Figure S4. *Probability density plot of water accumulation in dwellings without a cistern, with a water storage tank.*



Source: Own elaboration.

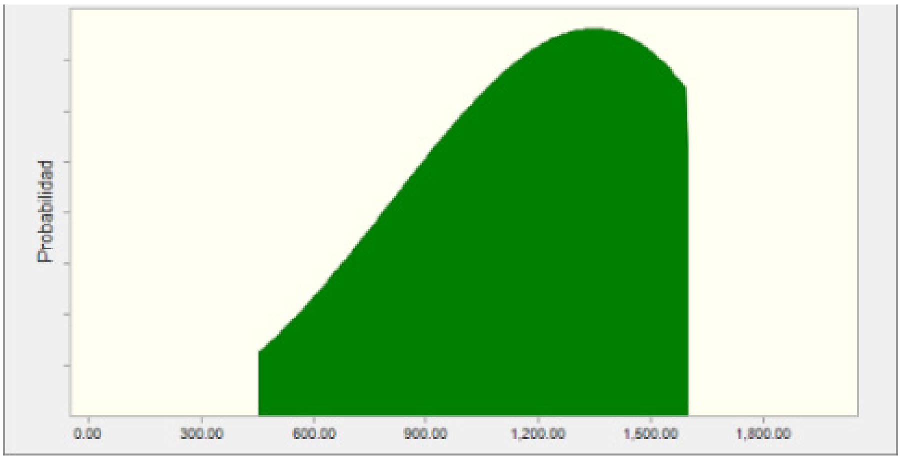
```
Estimated probability distribution information

Estimated location
Modes: 1101.907  1583.015
Antimode: 1462.649

Estimated value of the density
Modes: 0.001095601  0.0003955549
Antimode: 0.0003542053
```

Because the probability distribution has two modes, a compound rule of three was used to weight a single value for the mode, resulting in 1,346.32 liters.

While the estimated probability distribution extends into negative numbers, this is mathematically valid but not applicable to a real case, so a range between the maximum and minimum values of the summary statistics was chosen to trim the Beta PERT probability distribution.

```
Beta PERT distribution with the parameters:
        Mínimo                0.00
        Más probable          1,346.32
        Máximo                2,000.00

        The selected range was 450.00 to 1,600.00
```

Figure S5. *Beta PERT probability distribution for similar water storage capacity in dwellings with water tank.*



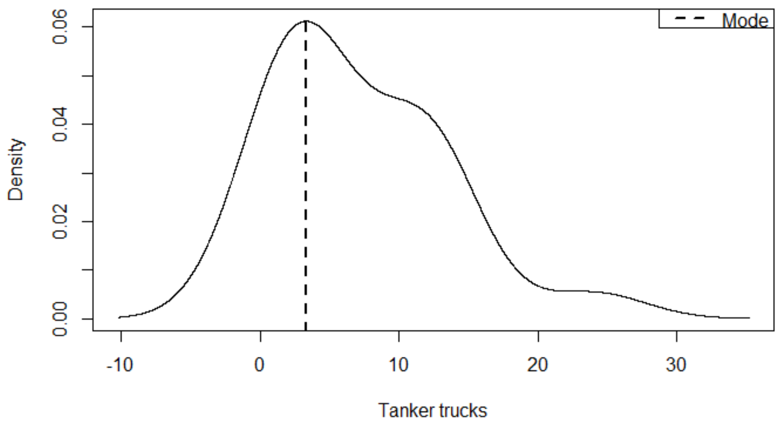
Source: Own elaboration.

Proposed probability distribution for the simulation of the number of tanker trucks supplying water to the dwellings with water tank (Pt)

Summary statistics and probability density of the information collected in the survey.

```
Summary of statistical parameters
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
   1.00    2.00    4.00    7.15   12.00   24.00      70
```

Figure S6. *Probability density plot of the number of tanker trucks supplying water to the dwellings with water tank.*



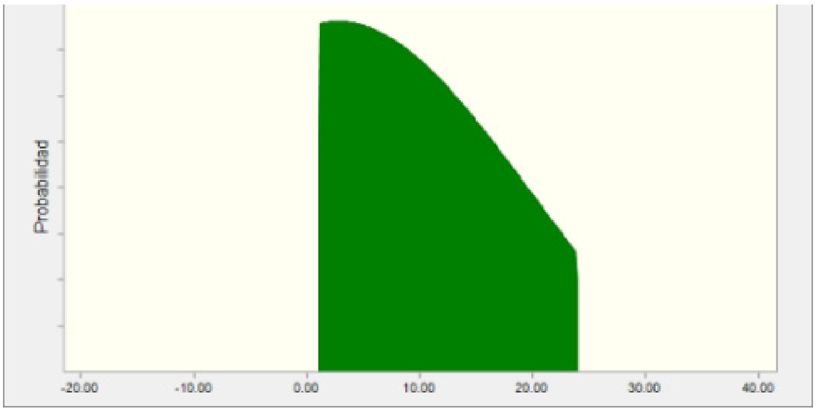
Source: Own elaboration.

```
Estimated probability distribution information
Estimated location
Mode: 3.321933

Estimated value of the density
Mode: 0.06122199

Critical bandwidth: 3.729542
```

The estimated probability distribution extends to negative numbers, which is valid mathematically but not applicable to this real-world case. As a result, a range between the maximum and minimum values of the summary statistics was selected to trim the Beta PERT probability distribution.

```
Beta PERT distribution with the parameters:
       Minimum                        -10.00
       More probable                   3.32
       Maximum                         35.00

The selected range was 1.00 to 24.00

Correlated with                                                    Coefficient
Number of tanker trucks supplying water to homes with water tanks        0.95
```

Figure S7. *Beta PERT probability distribution simulating the number of tanker trucks supplying water to the dwellings with water tanks.*



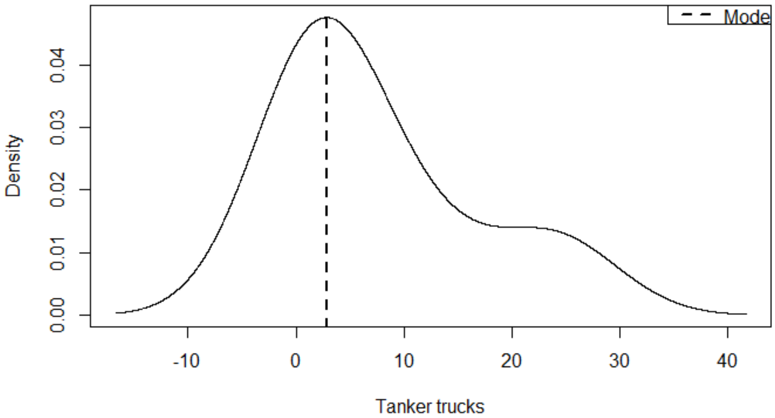
Source: Own elaboration.

Proposed probability distribution for the simulation of the number of tanker trucks supplying water to dwellings with cistern (Pc).

Summary statistics and probability density of the information collected in the survey.

```
Summary of statistical parameters
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
  1.000   2.000   3.000   7.545  12.000  24.000     109
```

Figure S8. *Probability density plot of the number of tanker trucks supplying water to dwellings with cistern.*



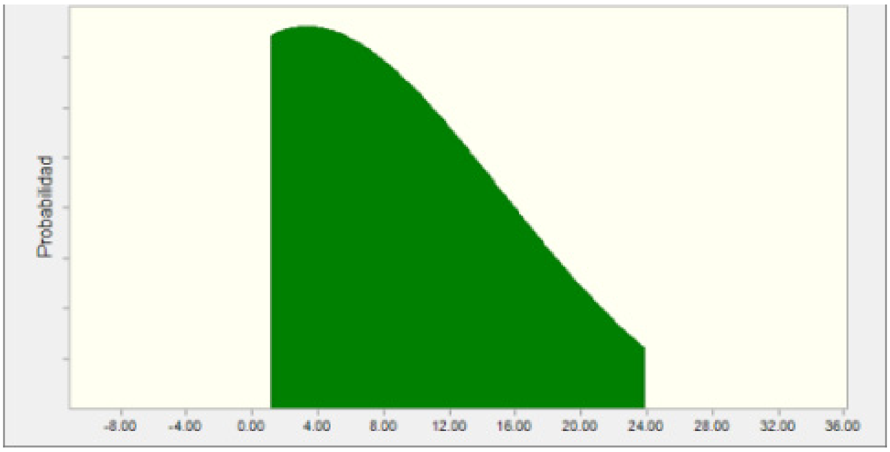
Source: Own elaboration.

```
Estimated probability distribution information
Estimated location
Mode: 2.836505

Estimated value of the density
Mode: 0.0475764

Critical bandwidth: 5.897275
```

The estimated probability distribution extends to negative numbers, which are mathematically valid but not applicable to a real case. Therefore, a range of positive values is established by using the maximum and minimum values of the summary statistics to trim the probability of the Beta PERT distribution.

```
Beta PERT distribution with the parameters:
       Minimum                -20.00
       More probable          2.84
       Maximum                40.00

The selected range was 1.00 to 24.00

Correlated with:                              Coefficient
       Number of tanker trucks supplying water to homes with cistern
                              0.95
```

Figure S9. *Proposed Beta Pert probability distribution for the simulation of the number of tanker trucks supplying water to dwellings with a water tank.*



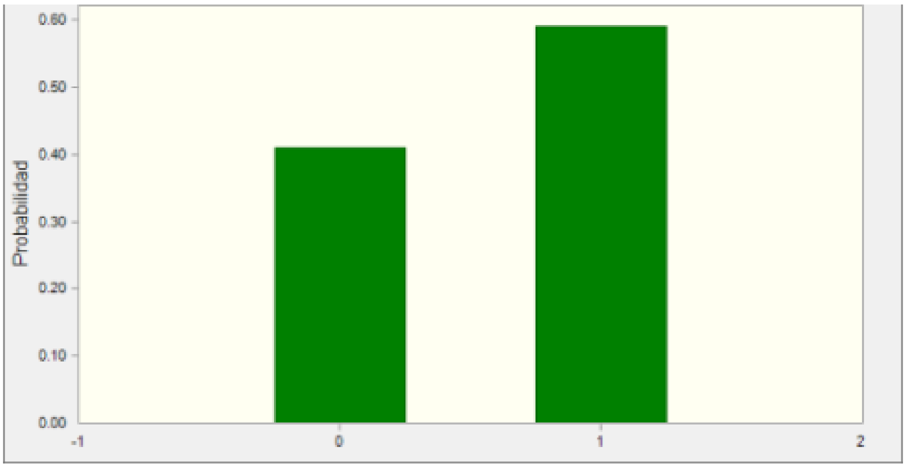
Source: Own elaboration.

Proposed probability distributions for the simulation of the ratio of dwellings with a cistern and with a water tank (Rc, Rt).

The INEGI official statistics (Census 2020) provide a ratio of 0.5903935 for dwellings with cistern, leaving dwellings without cistern at 0.4096065. The two variables are mutually exclusive so the correlation between them is -1. The "Yes-No" probability distribution parameters for the variable *Rc* are proposed as follows.

```
Yes-No distribution with the parameters:
       Probability of Yes(1)        0.5903935
       Correlated with:                                            Coefficient
       Ratio of dwellings with water tank                          -1.00
```

Figure S10. *Proposed "Yes-No" probability distribution for similar the ratio of dwellings that have a cistern (Rc).*



Source: Own elaboration.

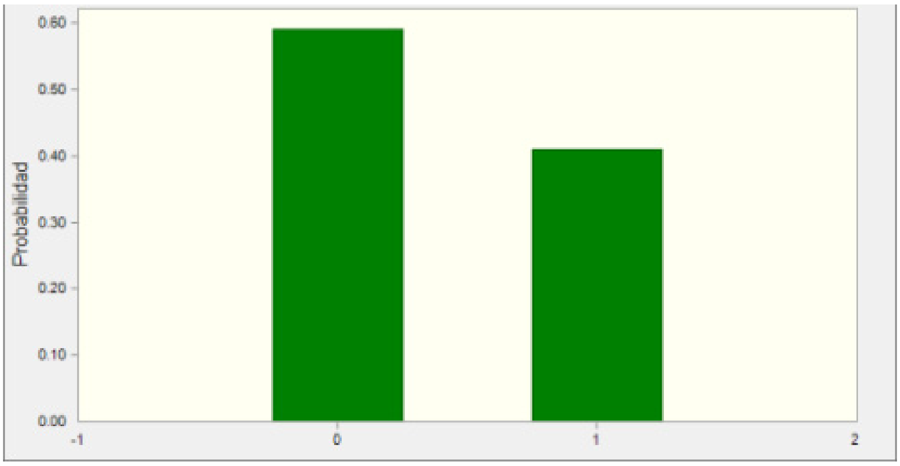
The parameters proposed in the "Yes-No" probability distribution for the simulation of the *Rt* variable are as follows.

```
Yes-No distribution with the parameters:
        Probability of Yes (1)                      0.4096065
```

Correlated with: `Coefficient`

```
Ratio of dwellings with cisterns                    -1.00
```

Figure S11. *Proposed "Yes-No" probability distribution for the ratio of dwellings that have a water tank (Rt).*



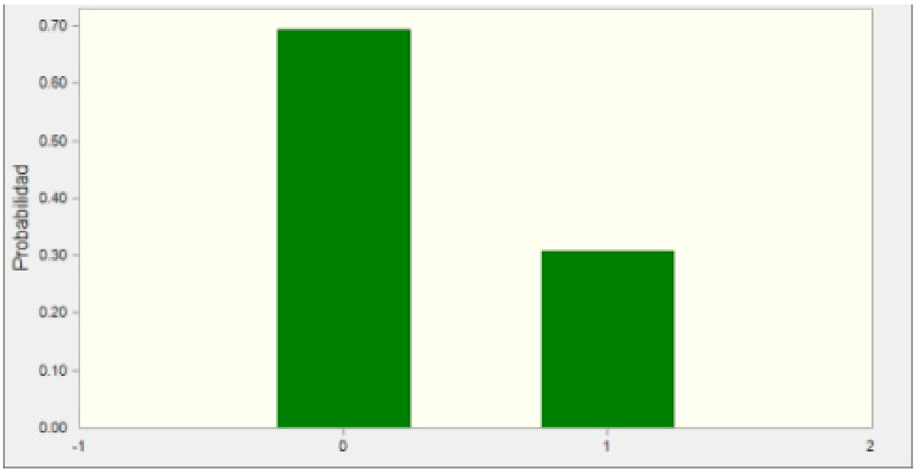
Source: Own elaboration.

Proposed probability distribution for the simulation of the ratio of dwellings with cistern supplied with water by tankers (Mcp, Mtp)

The survey yielded the percentage of dwellings using water trucks. Specifically, 30.67% of the dwellings with a cistern and 22.99% with a water tank require water truck service at least once a year. Additionally, the proposed parameters for the "Yes-No" probability distribution of variable Mcp are presented with its corresponding probability distribution.

```
Yes-No distribution with the parameters:
       Probability of Yes(1) 0.3066667
```

Figure S12. *"Yes-No" probability distribution simulating the ratio of dwellings with tankers receiving water service from tanker trucks (Mcp).*

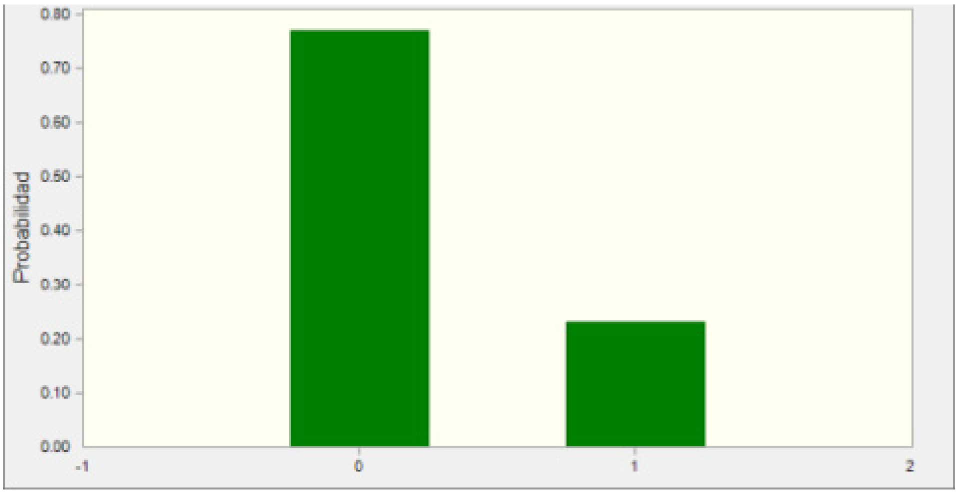


Source: Own elaboration.

The parameters proposed in the "Yes-No" probability distribution for the *Mtp* variable are as follows.

```
Yes-No distribution with the parameters:
       Probability of Yes(1) 0.2298851
```

Figure S13. *Yes-No probability distribution that simulates the ratio of dwellings with water tanks that are supplied with water by tanker trucks (Mtp).*



Source: Own elaboration.

Forecasts and sensitivity analysis (water transported in tanker trucks)

Overview of the Monte Carlo simulation.

```
Crystal report: complete
Simulation started on 05/18/2022 at 10:57 a.m.
Simulation stopped on 05/18/2022 at 11:02 a.m.

Execution preferences:
        Number of tests executed      20,000
        Monte Carlo
        Random initialization
        Precision control enabled
           Confidence level    95.00%.

Execution statistics:
Total run time (sec)  295.51
        Trials/second (average)       68
        Random numbers per second     2,504
```

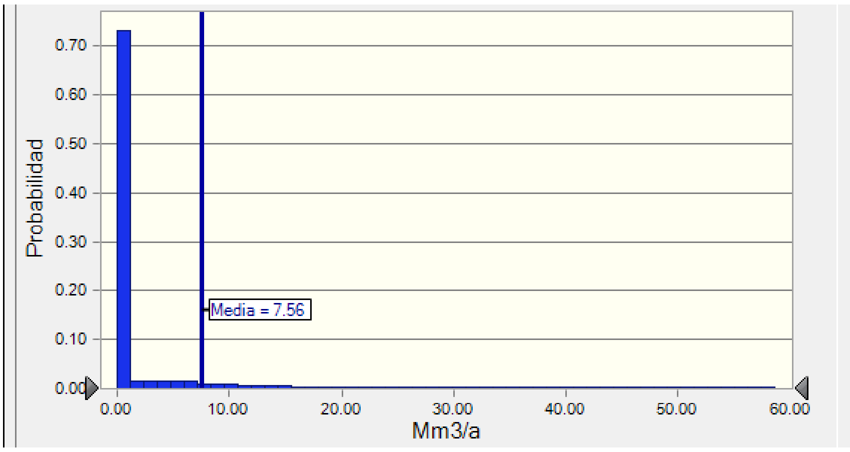
Equations S1and S2 were utilized in a Monte Carlo simulation for estimating the flow rates carried by tanker trucks for every type of dwelling. The total flow rate of water conveyed by tankers in the city was estimated using Equation S3.

$$Q_{tanker-t} = Q_{tanker-t,wt} + Q_{tanker-t,cis} \qquad \text{(S3)}$$

Forecast of the flow transported by tanker trucks for dwellings in the city ($Q_{tanker-t,wt}$)

```
Forecast:
Overview:
The full range is 0.00 to 125.12.
After 20,000 tests, the standard error of the mean is 0.13.
```

Figure S14. *Forecast of the flow transported by tanker trucks to supply the dwellings (Units in Mm^3/yr)*



Source: Own elaboration.

The following statistical values were obtained from the forecast.

Table S1. *Statistical data related to the prediction graph of the flow rate transported by tanker truck.*

Statistics:	Forecast values
Test	20,000
Base case	4.99
Mean	**7.56**
Median	0.00
Mode	0.00
Standard deviation	18.23
Variance	332.28
Bias	2.94
Kurtosis	11.78
Coefficient of variation	2.41
Minimum	0.00
Maximum	125.12
Range width	125.12
Mean standard error	0.13

The mean value is (7.56 Mm^3/year) was included in the Urban Water Metabolism model. The percentiles of the forecast distribution were as follows.

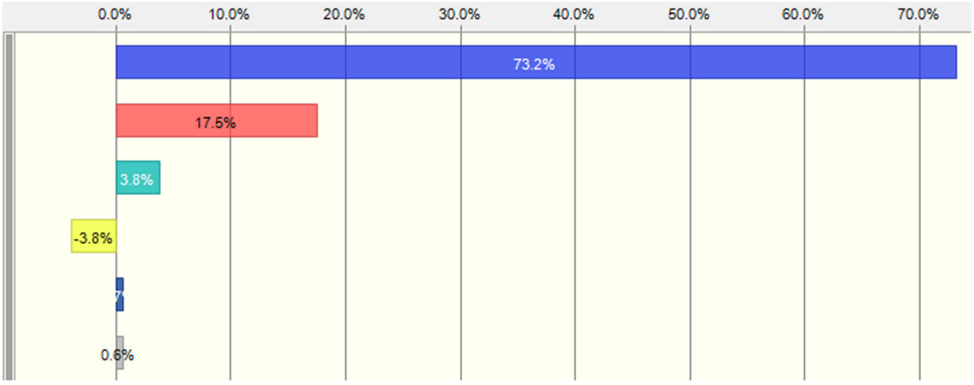
Table S2. *Percentiles related to the forecast graph of the flow rate transported by tanker truck.*

Percentiles:	Forecast values
0%	0.00
10%	0.00
20%	0.00
30%	0.00
40%	0.00
50%	0.00
60%	0.00
70%	0.00
80%	7.01
90%	30.84
100%	125.12

Sensitivity analysis

The sensitivity analysis is presented in Figure S15, depicting the first two variables as the proportion of dwellings receiving water via tanker trucks (*Mcp, Mtp*), followed by the ratio of dwellings with cisterns and water tanks (*Rc, Rt*), the number of tanker trucks per dwelling (*Pc, Pt*), and the water storage capacity in dwellings with cisterns and water tanks (*Ac, At*).

Figure S15. *Sensitivity graph of the prediction of the flow rate transported in tanker trucks.*



Source: Own elaboration.

Water storage capacity in the city's dwelling units. (A_{wt}, A_{cis})

Equations S4 to S6 are derived from equations S1 to S2. However, the latter did not include the term for the number of trucks supplying water to the residences.

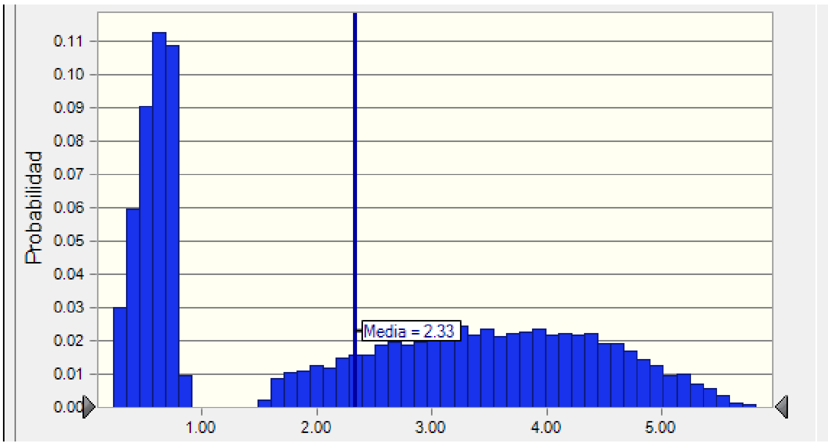
$$A_{wt} = Ac * Rc * Mcp * V/10^9 \quad \text{(S4)}$$

$$A_{cis} = At * Rt * Mtp * V/10^9 \quad \text{(S5)}$$

$$A_v = A_{wt} + A_{cis} \quad \text{(S6)}$$

```
Forecast:
Summary:
        The full range is 0.23 to 5.82.
        After 20,000 tests, the standard error of the mean is 0.01.
```

Figure S16. *Graph forecasting water storage capacity in the city's dwelling units. Units (Mm^3/yr)*



Source: Own elaboration.

The following statistical values were obtained from the predicted probability distribution.

Table S3. *Statistical summary of the forecast graph for the water storage capacity in households.*

Statistics:	Forecast values
Tests	20,000
Base case	2.22
Mean	2.33
Median	2.42
Mode	---
Standard deviation	1.64
Variance	2.69
Bias	0.1949
Kurtosis	1.56
Coefficient of variation	0.7051
Minimum	0.23
Maximum	5.82
Range width	5.59
Mean standard	0.01

The mean value (2.33 Mm^3/year) is used as an estimation of the total accumulation capacity in the dwellings. The percentiles of the predicted distribution are presented below.

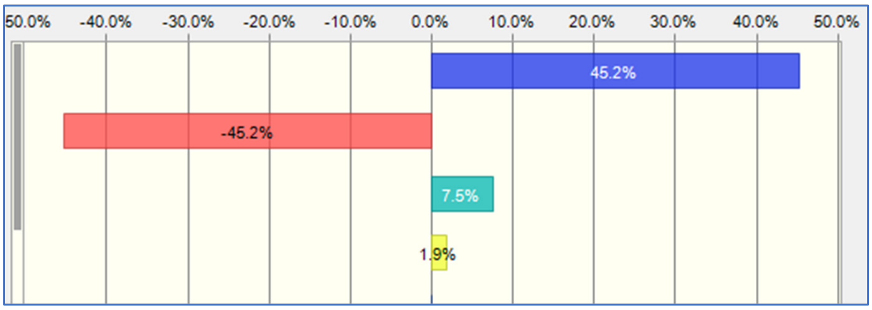
Table S4. *Percentiles of the forecasted graph for the accumulation capacity in residential units.*

Percentiles:	Forecast values
0%	0.23
10%	0.47
20%	0.59
30%	0.69
40%	0.80
50%	2.42
60%	3.02
70%	3.53
80%	4.04
90%	4.57
100%	5.82

Sensitivity analysis

Figure S17 displays the graph for sensitivity analysis, with the first two variables representing the ratio of homes with cisterns and water tanks (*Rc, Rt*) and the following two corresponding to the water storage capacity in homes with cisterns and water tanks (*Ac, At*). The results obtained are meaningful because the storage capacity is related to the installed infrastructure and this is independent of the number of tankers requested per dwelling.

Figure S17. *Sensitivity plot of forecast water storage capacity in dwelling units.*



Source: Own elaboration.

Estimation of bottled water flow rate.

From the data gathered in the survey, we initially estimated the bottled water consumption per household (*Lv1, Lv2, Lv3, Lv4*, equations 10 to 13). Subsequently, equations 14 to 17 were utilized to compute the flow rate of bottled water for each container category. The above equations contain the following terms: the ratio of households that consume bottled water (*Rba*); the total number of households (*V*), which is already known; and both are multiplied by 365 to convert liters per day into liters per year, and then divided by 109 to convert liters per year into cubic hectometers per year.

$$Q_{em1} = L_{v1} * Rba * V * 365/10^9 \qquad (S7)$$

$$Q_{em2} = L_{v2} * Rba * V * 365/10^9 \qquad (S8)$$

$$Q_{em3} = L_{v3} * Rba * V * 365/10^9 \qquad (S9)$$

$$Q_{er} = L_{v4} * Rba * V * 365/10^9 \qquad (S10)$$

Definition of assumptions for Monte Carlo simulation (Bottled water)

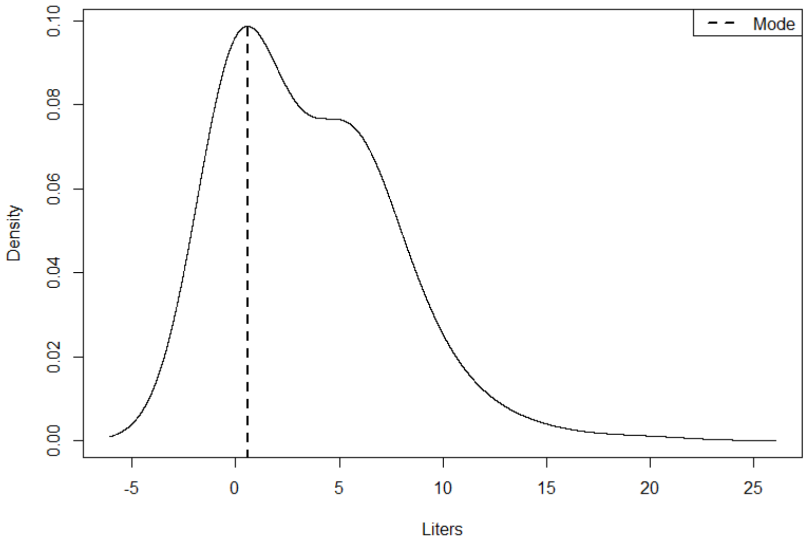
We establish the initial assumptions for the Monte Carlo simulation of the variables mentioned in equations S7 and S10.

Proposed probability distribution for the simulation of the flow rate of bottled water in 20-liter carboys (Marca Grande). (L_{v1})

Summary statistics and probability density of the information collected in the survey.

```
Summary of statistical parameters
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  0.000   0.000   2.857   3.485   5.714  20.000
```

Figure S18. *Probability density plot of daily consumption of bottled water in 20-liter Big-brand carboys.*



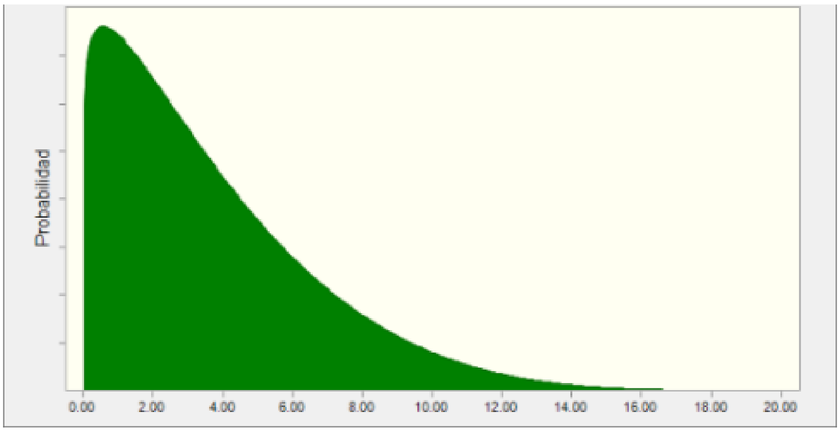
Source: Own elaboration.

```
Estimated probability distribution information

Estimated location
Mode: 0.5700754

Estimated value of the density
Mode: 0.09878381

Critical bandwidth: 2.019651
```

Based on the previous information, the parameters of minimum, maximum, and mode were proposed in a Beta PERT probability distribution.

```
Beta PERT distribution with the parameters:
        Minimum                 0.00
        More probable           0.57
        Maximum                 20.00

        The selected range was 0.00 to ∞

Correlated with:                                Coefficient
Carafe Big Brand 5L                             0.00
        Botella 1.5L                            0.11
```

Figure S19. *Beta PERT probability distribution for similar consumption of bottled water in 20-liter carboys (Big brand).*



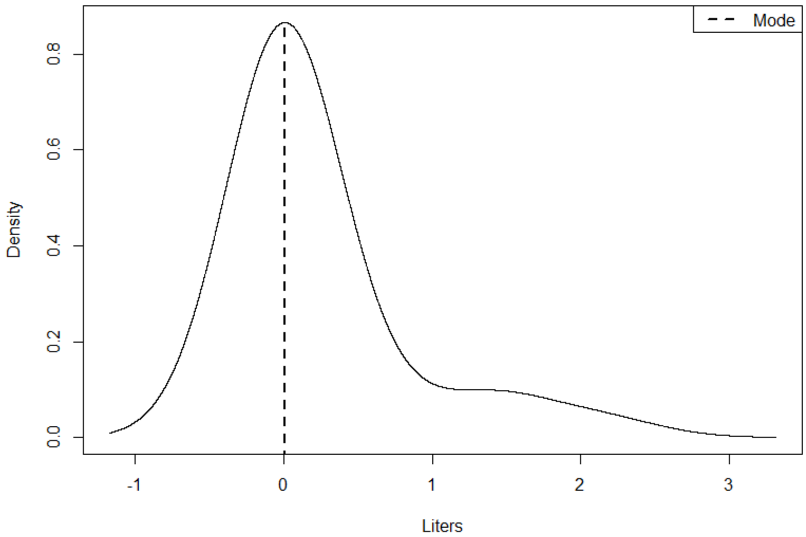
Source: Own elaboration.

Proposed probability distribution for the simulation of water flow rate in 5-liter carafes (Big brand) (L_{v2})

Summary statistics and probability density of the information collected in the survey.

```
Summary of statistical parameters
    Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
 0.0000  0.0000  0.0000  0.2273  0.0000  2.1429 
```

Figure S20. *Probability density plot of daily consumption of bottled water in 5-liter carafes (Big brand).*



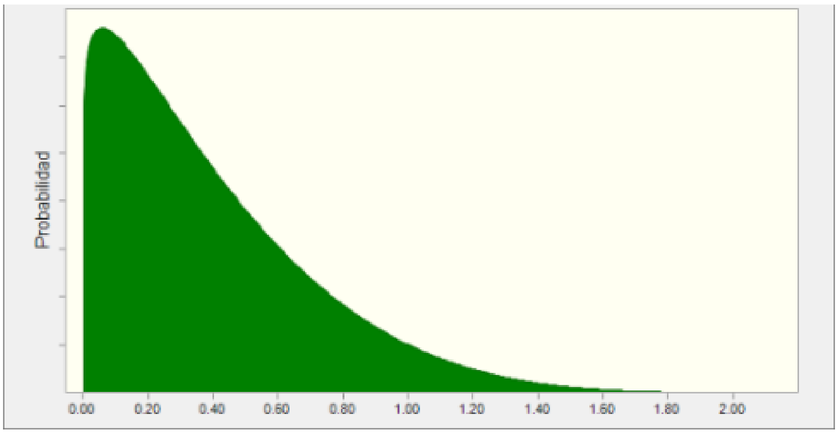
Source: Own elaboration.

```
Estimated probability distribution information

Estimated location
Mode: 0.007549853

Estimated value of the density
Mode: 0.8659185

Critical bandwidth: 0.3896942
```

Based on the previous information, the parameters of minimum, maximum, and mode were proposed in a Beta PERT probability distribution.

```
Beta PERT distribution with the parameters:
Minimum                0.00
More probable          0.06
Maximum                2.14

The selected range was 0.00 to ∞

Correlated with:                                                    Coefficient
Big brand bottled water flow in 1.5 liter bottles (Lv3)           0.29
Big brand bottled water flow in 20 liter carboys (Lv1)            0.00
```

Figure S21. *Proposed probability distribution for the simulation of the flow rate of bottled water in 5 liter carafes (Big brand).*



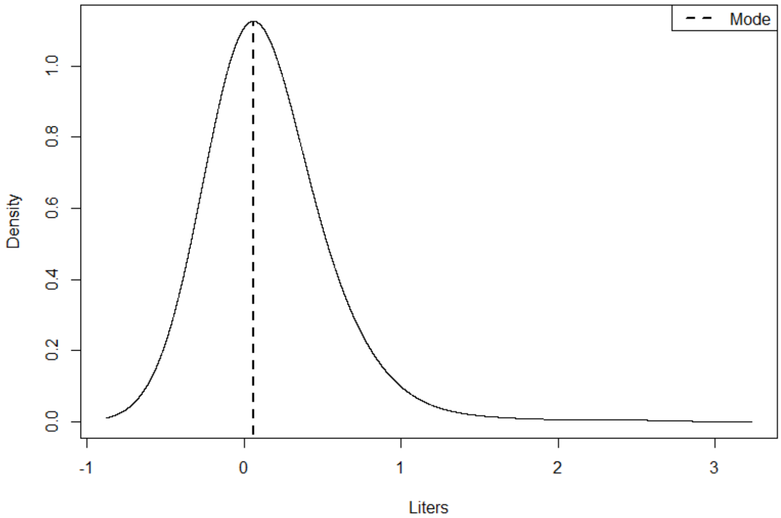
Source: Own elaboration.

Proposed distribution probability for the simulation of the flow rate of bottled water in 1.5 liter bottles (Big brand). (L_{v3})

Summary statistics and probability density of the information collected in the survey.

```
Summary of statistical parameters
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.0000  0.0000  0.0000  0.1534  0.2143  2.3571
```

Figure S22. *Probability density of daily consumption of bottled water in 1.5 liter bottles (Big brand).*



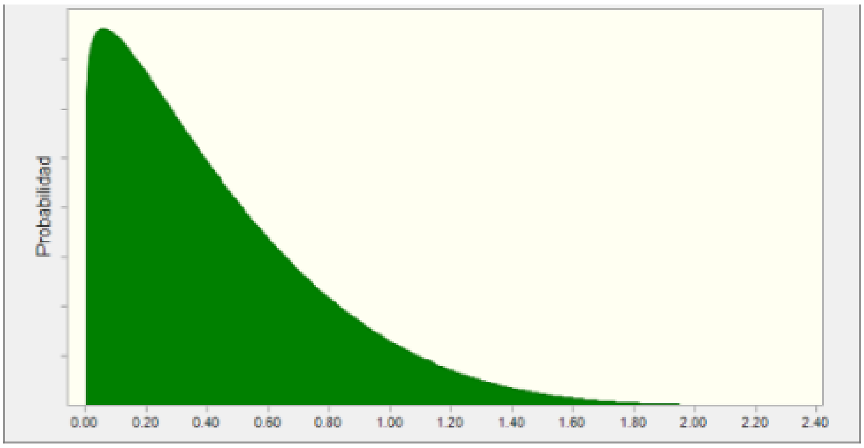
Source: Own elaboration.

```
Estimated probability distribution information

Estimated location
Mode: 0.05880532

Estimated value of the density
Mode: 1.125218

Critical bandwidth: 0.2919006
```

Based on the previous information, the parameters of minimum, maximum, and mode were proposed in a Beta PERT probability distribution.

```
Beta PERT distribution with the parameters:
        Minimum              0.00
        More probable        0.06
        Maximum              2.36

        The selected range was 0.00 to ∞

Correlated with:                                Coefficient
Big brand bottled water flow in 5 liter carafes (Lv2)           0.29
Big brand bottled water flow in 20 liter carboys (Lv1)     0.11
```

Figure S23. *Beta PERT probability distribution for similar consumption of bottled water in 1.5 liter bottles (Big Brand).*



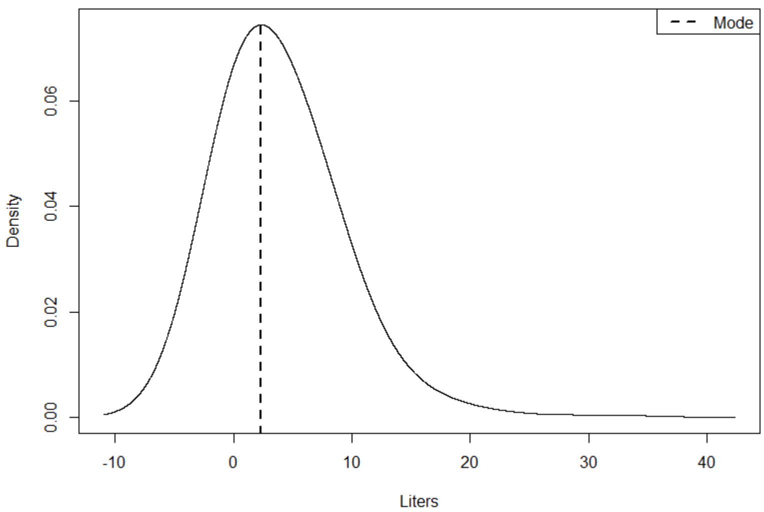
Source: Own elaboration.

Proposed probability distribution for the simulation of the flow rate of bottled water in 20-liter carboys (refill) (L_{v4})

Summary statistics and probability density of the information collected in the survey.

```
Summary of statistical parameters
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  0.000   0.000   2.857   3.918   5.714  31.429
```

Figure S24. *Probability density of daily consumption of refillable bottled water in 20-liter carboys (LPWC's).*



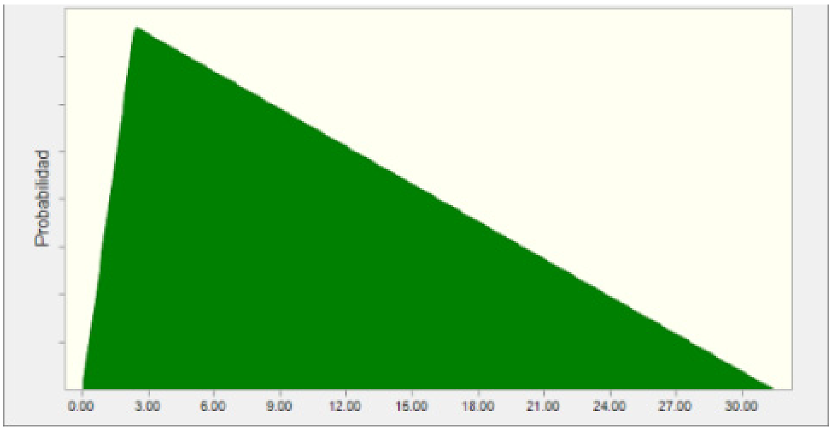
Source: Own elaboration.

```
Estimated probability distribution information
Estimated location
Mode: 2.351329

Estimated value of the density
Mode: 0.07448657

Critical bandwidth: 3.633989
```

A triangular probability distribution was employed to enhance the magnitude of the estimation. This decision was based on the information gathered in the survey, which indicated the existence of at least as many clandestine water purification plants as official ones.

```
Assumption: Refill · Simulation Garr
Triangular distribution with the parameters:
        Minimum                         0.00
        More probable                   2.35
        Maximum                         31.43
Correlated with:                                                Coefficient
Big brand bottled water · Simulation
Big brand bottle water total (Lv1+Lv2+Lv3)               -0.56
```

Figure S25. *Triangular probability distribution for the simulation of water flow rate in 20-liter refill carboys.*



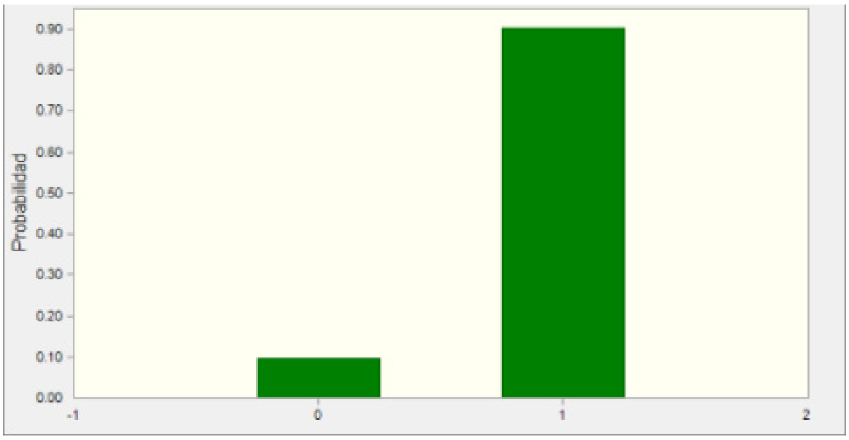
Source: Own elaboration.

Proposed probability distribution for the simulation of the ratio of the population consuming bottled water (Rba)

According to survey data, tap water is not consumed in 90.23% of dwellings. To simulate variable Rba, a "Yes-No" probability distribution was employed with the following parameters.

```
Yes-No distribution with the parameters:
        Probability of Yes(1) 0.9023438
```

Figure S26. *"Yes-No" probability distribution for simulating the ratio of dwellings where bottled water is consumed.*



Source: Own elaboration.

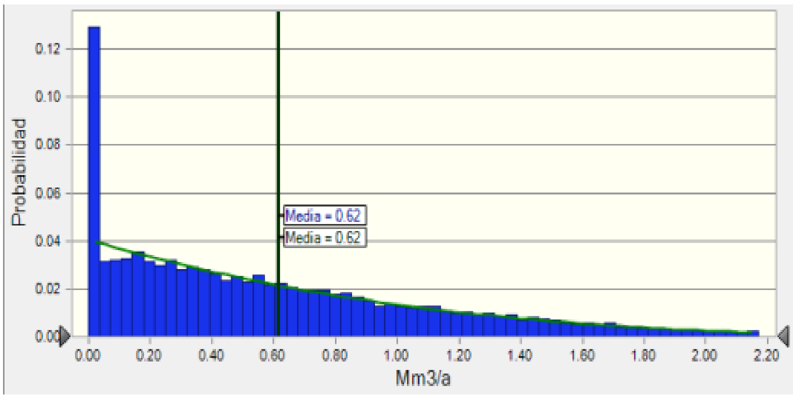
Forecasting and sensitivity analysis (bottled water)

```
Crystal report: complete
Simulation started on 05/18/2022 at 10:57 a.m.
Simulation stopped on 05/18/2022 at 11:02 a.m.

Execution preferences:
        Number of tests executed      20,000
        Monte Carlo
        Random initialization
        Precision control enabled
           Confidence level    95.00%.

Execution statistics:
Total run time (sec)   295.51
        Trials/second (average)       68
        Random numbers per second     2,504
```

Forecast of the flow of bottled water in 20-liter carboys (Big brand) (Q_{em1}).

```
Forecast:
Summary:
        The full range is 0.00 to 3.29.
        After 20,000 tests, the standard error of the mean is 0.00.
```

Figure S27. *Graph of bottled water flow forecast in 20 liter jugs (large brand), units (Mm³/year)*



Source: Own elaboration.

The following statistical values relate to the probability distribution.

Table S5. *Statistical summary of the forecast graph of the flow rate of bottled water in 20-liter carboys (Big brand).*

Statistics:	**Forecast values**
Tests	20,000
Base case	0.58
Mean	0.62
Median	0.48
Mode	0.00
Standard deviation	0.56
Variance	0.31
Bias	1.08
Kurtosis	3.81
Coefficient of variation	0.9025
Minimum	0.00
Maximum	3.29
Range width	3.29
Mean standard error	0.00

The average value (0.62 Mm^3/year) was incorporated into the Urban Water Metabolism model for the city of Puebla. The distribution of the percentiles is outlined below.

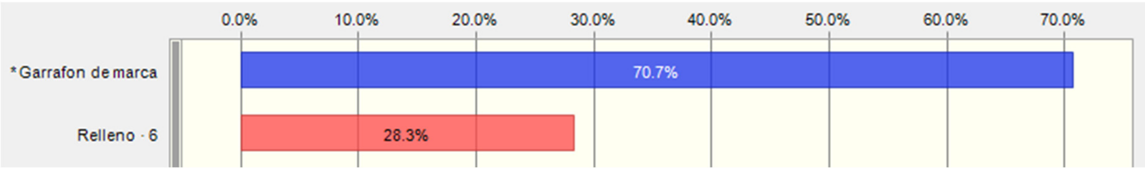
Table S6. *Percentiles of the forecast graph of the flow rate of bottled water in 20-liter carboys (Big brand).*

Percentiles:	Forecast values
0%	0.00
10%	0.00
20%	0.11
30%	0.22
40%	0.34
50%	0.48
60%	0.63
70%	0.81
80%	1.06
90%	1.42
100%	3.29

Sensitivity analysis

Figure S28 shows the sensitivity analysis. The first variable (*Lv1*) refers to the number of liters of water consumed by the market transported in 20-litre carboys, and the second variable (*Rba*) refers to the number of dwellings in which bottled water is consumed.

Figure S28. *Sensitivity chart of the forecast flow rate of bottled water in 20-liter carboys consumed in dwellings (Big brand).*

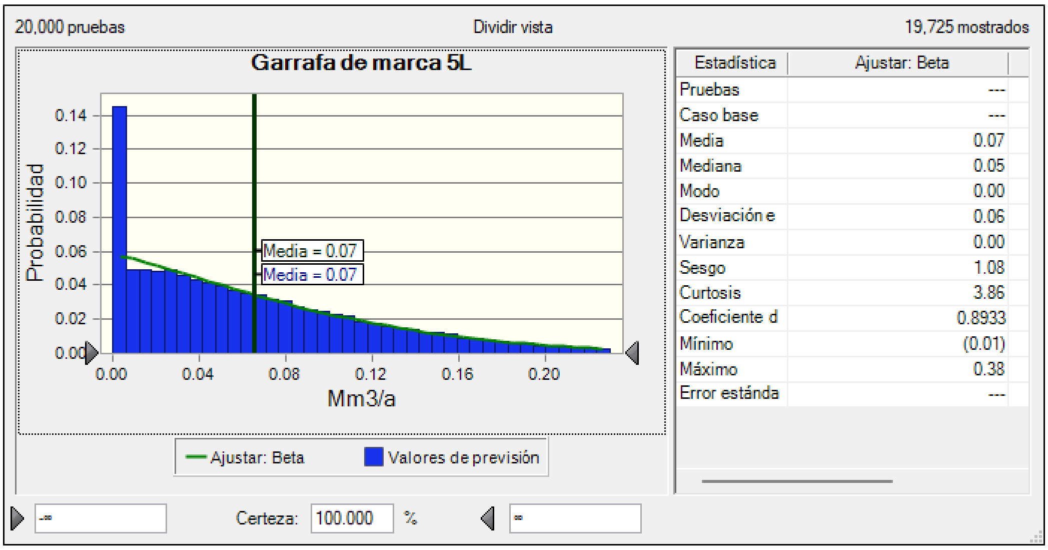


Source: Own elaboration.

Forecast flow rate of bottled water in 5-liter carafes (Big brand) (Q_{em2})

```
Forecast:

Summary:
        The full range is 0.00 to 0.36.
        After 20,000 tests, the standard error of the mean is 0.00.
```

Figure S29. *Graph of bottled water flow forecast in 5-liter carafes (Big brand). Units (Mm³/year)*



Source: Own elaboration.

The following statistical values relate to the probability distribution.

Table S7. *Statistical information of the forecast graph of the flow of bottled water in 5-liter carafes (Big brand).*

Statistics:	**Forecast values**
Tests	20,000
Base case	0.04
Mean	0.07
Median	0.05
Mode	0.00
Standard deviation	0.06
Variance	0.00
Bias	1.08
Kurtosis	3.86
Coefficient of variation	0.8934
Minimum	0.00
Maximum	0.36
Range width	0.36
Mean standard error	0.00

The mean value (0.07 Mm^3/a) was included in the Urban Water Metabolism model. The percentile distribution is shown below.

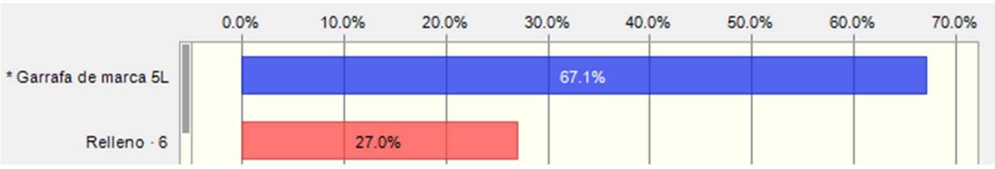
Table S8. *Percentiles of the forecast graph of the flow rate of bottled water in 5-liter carafes (Big brand).*

Percentiles:	Forecast Value
0%	0.00
10%	0.00
20%	0.01
30%	0.02
40%	0.04
50%	0.05
60%	0.07
70%	0.09
80%	0.11
90%	0.15
100%	0.36

Sensitivity analysis

Figure S30 shows the sensitivity analysis where the first variable represents the liters of bottled water transported in 5-liter jugs (*Lv2*), and the second variable represents the ratio of dwellings where bottled water is consumed (*Rba*).

Figure S30. *Sensitivity analysis graph for forecasting the flow of bottled water in 5-liter carafes (Big brand)..*



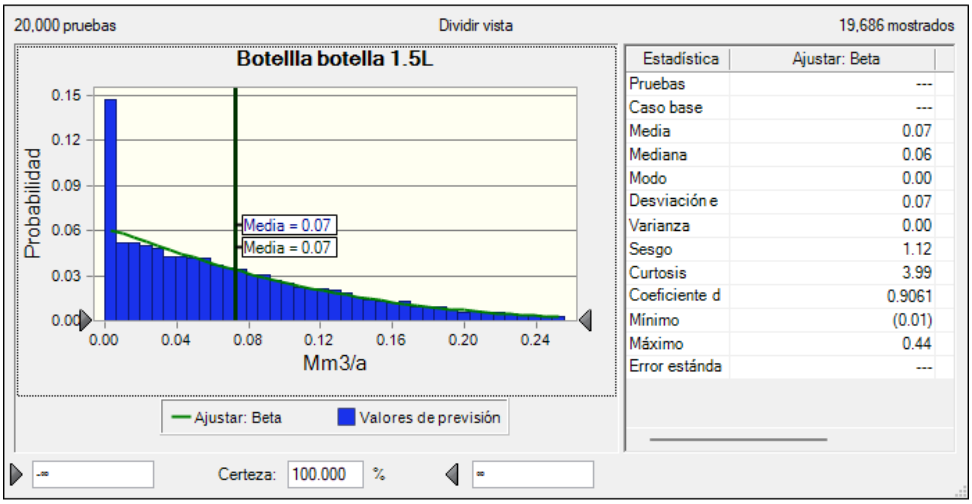
Source: Own elaboration.

Forecast flow rate of bottled water in 1.5 liter bottles (Big brand) (Q_{em3})

Forecast Summary:

The full range is 0.00 to 0.40
The base case is 0.03
After 20,000 tests, the standard error of the mean is 0.00.

Figure S31. *1.5 liter bottled water flow rate forecast graph (Big brand), units (Mm^3/year).*



Source: Own elaboration.

The statistical information obtained from the probability distribution is presented below.

Table S9. *Statistical data of the forecast graph of the flow rate of bottled water in 5-liter bottles (Big brand).*

Statistical:	Forecast values
Tests	20,000
Base case	0.03
Mean	0.07
Median	0.06
Mode	0.00
Standard deviation	0.07
Variance	0.00
Bias	1.12
Kurtosis	3.99
Coefficient of variation	0.9061
Minimum	0.00
Maximum	0.40
Range width	0.40
Mean standard error	0.00

The mean value (0.07 Mm3/a) was included in the Urban Water Metabolism model. The percentiles of the forecasted probability distribution are presented below.

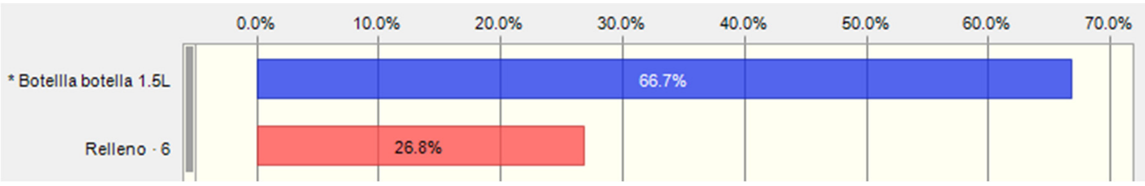
Table S10. *Percentiles of the flow rate forecast graph of bottled water in 1.5-liter bottles (Big brand).*

Percentiles:	Forecast values
0%	0.00
10%	0.00
20%	0.01
30%	0.03
40%	0.04
50%	0.06
60%	0.07
70%	0.10
80%	0.12
90%	0.17
100%	0.40

Sensitivity analysis

The sensitivity analysis shown in Figure S32 shows the first variable as the liters of bottled water consumed in 1.5-liter bottles (*Lv3*), the second variable corresponds to the ratio of dwellings where bottled water is consumed (*Rba*).

Figure S32. *Sensitivity plot of the forecast flow rate of bottled water in 1.5 liter bottles (large brand).*

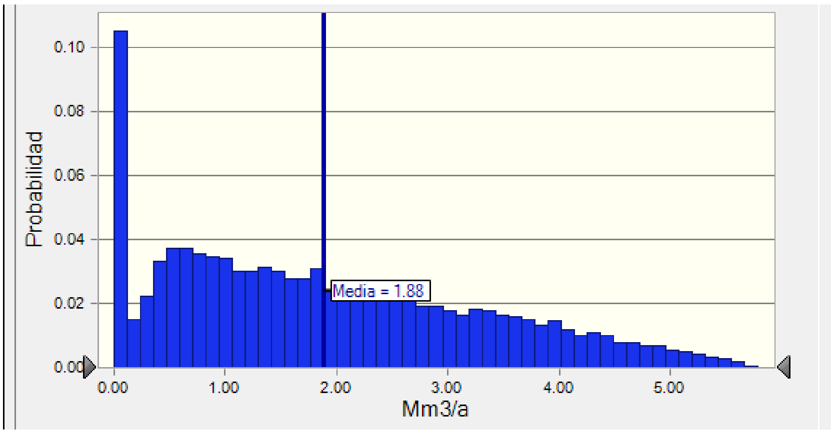


Source: Own elaboration.

Forecast flow rate of bottled water in 20-liter carboys (refilling) (Q_{emr})

```
Forecast:
        Summary:
                The full range is 0.00 to 5.78.
                The base case is 0.66
                After 20,000 trials, the standard error of the mean is 0.01
```

Figure S33. *Forecast graph of bottled water flow in 20-liter carboys (refill). Units (Mm³/year)*



Fuente: Elaboración propia.

The following statistical values were obtained from the forecasted probability distribution.

Table S11. *Statistical summary of the forecast graph of the flow of bottled water in 20-liter carboys (refill).*

Statistics:	**Forecast values**
Tests	20,000
Case base	0.66
Mean	1.88
Median	1.64
Mode	0.00
Standard deviation	1.41
Variance	1.98
Bias	0.5452
Kurtosis	2.38
Coefficient of variation	0.7489
Minimum	0.00
Maximum	5.78
Range width	5.78
Mean standard error	0.01

The mean value (1.88 Mm^3/a) was included in the Urban Water Metabolism model. The percentiles of the predicted distribution graph are presented below.

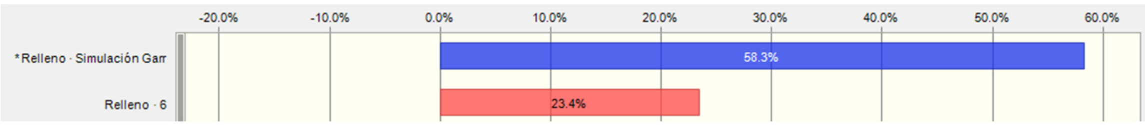
Table S12. *Percentiles of the forecast graph of bottled water in 20-liter carboys (refill).*

Percentiles:	Forecast value
0%	0.00
10%	0.06
20%	0.55
30%	0.88
40%	1.25
50%	1.64
60%	2.08
70%	2.59
80%	3.21
90%	3.96
100%	5.78

Sensitivity analysis

The sensitivity analysis is shown in Figure S34, where the first variable corresponds to the liters consumed of big brand water transported in 20-liter carboys (*Lv4*), the second variable corresponds to the ratio of dwellings where bottled water is consumed (*Rba*).

Figure S34. *Sensitivity plot of bottled water flow forecasting in 20-liter carboys (refill).*



Source: Own elaboration.

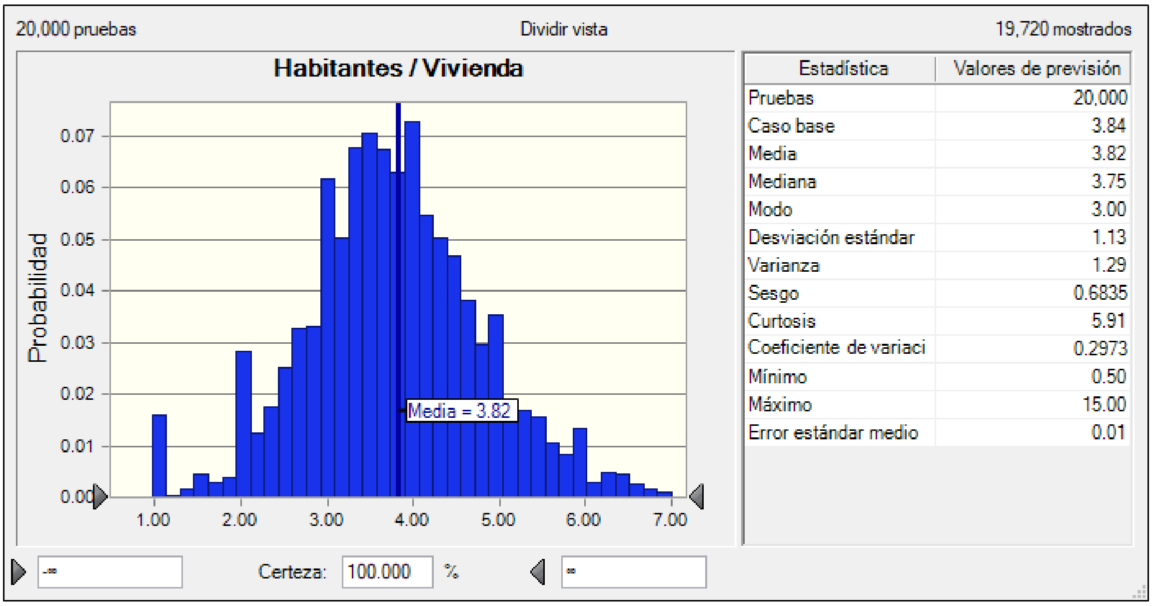
Information obtained with Monte Carlo simulation compared with statistical information taken from the INEGI census.

The Monte Carlo simulation of the population per dwelling and the total population in the central city obtained from the INEGI census are shown below.

Inhabitants per dwelling

```
Forecast:  Summary:
        The full range is from 0.50 to 15.00.
        After 20,000 trials, the standard error of the mean is 0.01.
```

Figure S35. *Graph of forecast number of inhabitants per dwelling, units (dwelling inhabitants)*



Source: Own elaboration.

Table S13. *Statistical summary of the forecast of the number of inhabitants per dwelling.*

Statistics:	Forecast values
Test	20,000
Base case	3.84
Mean	3.82
Median	3.75
Mode	3.00
Standard deviation	1.13
Variance	1.29
Bias	0.6835
Kurtosis	5.91
Coefficient of variation	0.2973
Minimum	0.50
Maximum	15.00
Range width	14.50
Mean standard error	0.01

The Monte Carlo simulation estimates that there are 3.82 inhabitants per dwelling, which is 3.4% higher than the INEGI mean of 3.639 inhabitants per dwelling in 2020. This difference is attributed to the fact that the survey respondents mostly reside in areas with higher population densities.

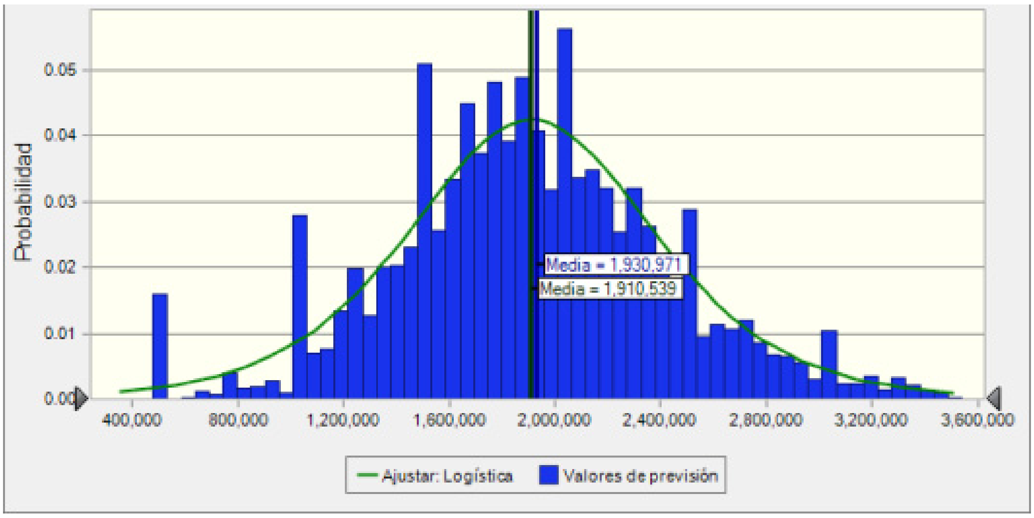
Table S14. *Percentiles of the forecast number of inhabitants per Dwelling.*

Percentiles:	Forecast values
0%	0.50
10%	2.50
20%	3.00
30%	3.26
40%	3.50
50%	3.75
60%	4.00
70%	4.26
80%	4.62
90%	5.16
100%	15.00

Inhabitants per dwelling in the Water Company's coverage area.

```
Forecast:
        Summary:
                The full range is 253,010 to 7,590,285.
                After 20,000 tests, the standard error of the mean is 4.059.
```

Figure S36. *Total population in the central city (dwellings in the water company's coverage area)*



Source: Own elaboration.

Table S15. *Statistical summary of the total population forecast in the water utility's coverage area.*

Statistics:	Forecast values
Tests	20,000
Base case	1,945,175
Mean	1,930,971
Median	1,897,571
Mode	1,518,057
Standard deviation	574,097
Variance	329,587,821,311
Bias	0.6835
Kurtosis	5.91
Coefficient of variation	0.2973
Minimum	253,010
Maximum	7,590,285
Range width	7,337,276
Mean standard error	4,059

The mean of the Monte Carlo simulation was 1,930,971, which is 4.86% higher than the population served by the water utility in 2015, which was 1,841,500 included in Martinez-Austria & Vargas-Hidalgo (2016). This magnitude difference suggests that the survey respondents consisted of residents from densely populated areas, although a slight population increase between 2015 to 2021 may have also contributed.

Table S16. *Percentiles of total population forecast in water utility coverage.*

Percentiles:	Forecast values
0%	253,010
10%	1,265,048
20%	1,518,057
30%	1,649,247
40%	1,771,067
50%	1,897,571
60%	2,024,076
70%	2,156,081
80%	2,337,326
90%	2,611,058
100%	7,590,285