

Class 2b: Review of concepts in Probability and Statistics

Business Forecasting

Summarizing Data

Summary Statistics

Measures of Central Tendency

Mean

- **Mean** represents the arithmetic average of the data.
- The population mean μ is the sum of all observations divided by the total population size:

$$\mu = E(X) = \frac{\sum_{i=1}^N x_i}{N}$$

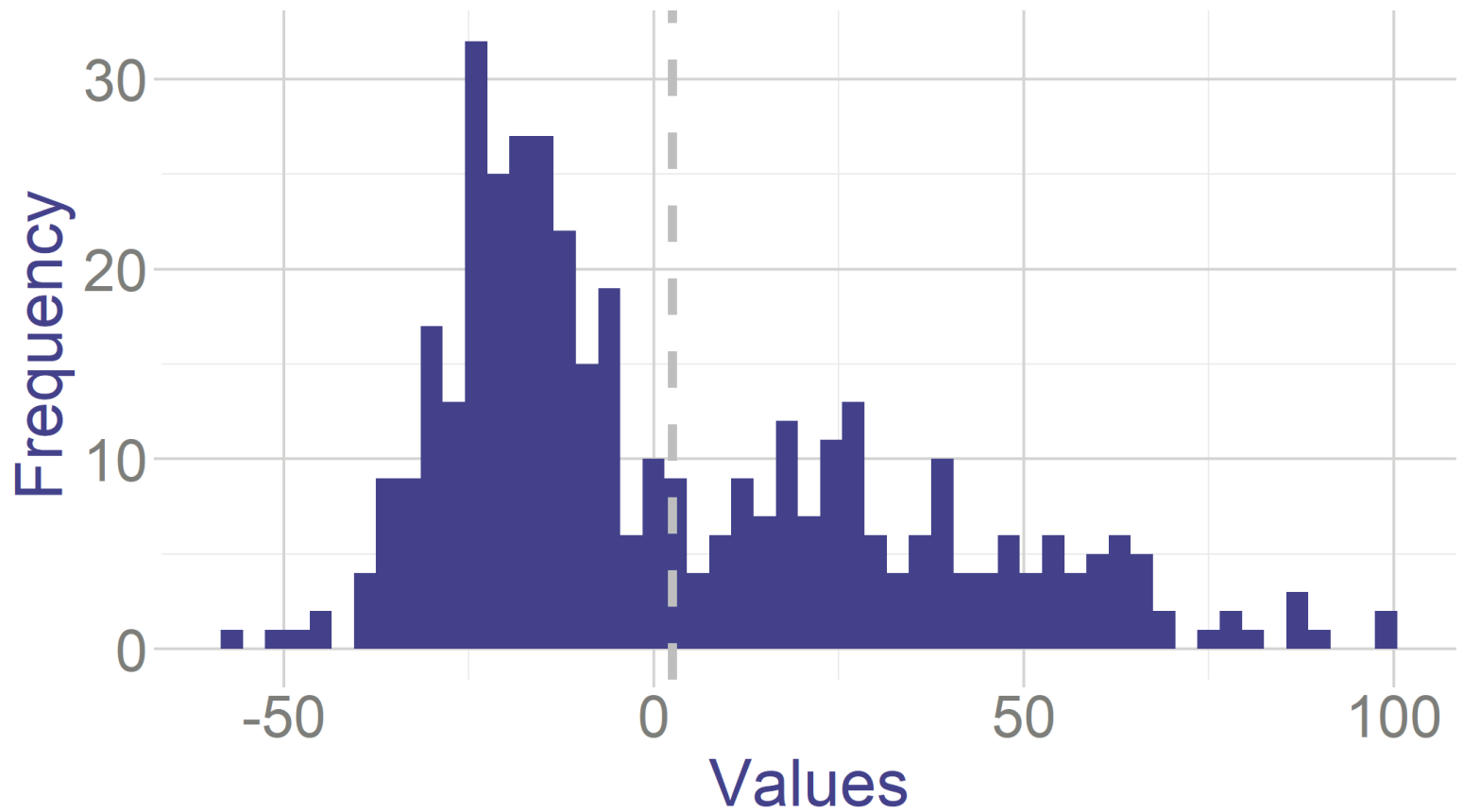
- where N is the total population size, and x_i are individual data points.
- The sample mean, denoted as \bar{x} , is the sample equivalent:

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n} = \frac{x_1 + x_2 + \dots + x_{n-1} + x_n}{n}$$

where n is the sample size.

Mean

Intuitively, mean is the balancing point of the distribution.



Mean of a binary variable

What is the mean of a **binary variable**?

- Binary variable is a variable which takes value 0 or 1
- For example: do you have diabetes (yes=1, no=0)

What is the intuitive interpretation of the mean of this variable?

- $\bar{x} = \frac{\sum_{i=1}^n x_i}{n}$
- $\bar{x} = \frac{1+0+0+\dots+0+1}{n} = \frac{n_{diabetes}}{n} = \hat{\mu}_{diabetes}$

It's the proportion of people with diabetes in the sample: $\text{mean}(\text{diabetes}) = 0.11$

Weighted Mean

- In some scenarios, data points have different weights.
- For a dataset with weights w_i and values x_i , the weighted mean is:

$$\text{Weighted Mean} = \frac{\sum_{i=1}^n w_i \cdot x_i}{\sum_{i=1}^n w_i}$$

Show entries

Person	Weight	Grade
Midterm 1	0.2	6
Midterm 2	0.2	8
Quizzes	0.15	9
Final Project	0.15	4

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The **weighted mean** is:

$$\bar{x} = \frac{0.2 \times 6 + 0.2 \times 8 + 0.15 \times 9 + 0.15 \times 4 + 0.3 \times 8}{0.2 + 0.2 + 0.15 + 0.15 + 0.3}$$

Aggregated Data

- We want to know average income in Mexico City.
- But we only know averages by neighborhood, no individual data

Show entries

Neighborhood	Average_Income	Population
Polanco	60000	10000
Condesa	45000	20000
Roma	35000	30000
Tepito	15000	5000
Coyoacán	30000	25000
Santa Fe	25000	18000

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Unweighted Mean vs. Weighted Mean

- Unweighted mean is: 25916.67 USD
- Weighted mean is: 21760.42USD
- Which one reflects average population income in CDMX?

$$\mu = \frac{\sum_{i=1}^N x_i}{N} = \frac{\sum_z \sum_{i=1}^{N_z} x_i}{\sum_z N_z} = \frac{\sum_z \frac{N_z}{N_z} \sum_{i=1}^{N_z} x_i}{\sum_z N_z} = \frac{\sum_z N_z \sum_{i=1}^{N_z} \frac{x_i}{N_z}}{\sum_z N_z} = \frac{\sum_z N_z \bar{x}_z}{\sum_z N_z}$$

Mean

- Is mean always a right measure?

"Bill Gates walks into a bar"

- Suppose a group of people, including Bill Gates, walks into a bar.
- Let's say the net worth of everyone in the group is as follows:

Show entries

Person	Net_Worth
Person 1	10
Person 2	20
Person 3	30
Person 4	40
Person 5	50
Bill Gates	600000

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The **mean** is:

$$\bar{x} = \frac{10 + 20 + 30 + 40 + 50 + 60000}{6}$$
$$= 100025$$

Mean is seriously skewed due to the outlier.

Mean vs Median



Median

- **Median** represents the middle value when data is sorted
- Half of observations are below it, half are above it.
- For a dataset with odd size n , the median is the $\frac{n+1}{2}$ -th value
- For even size n , it's the average of $\frac{n}{2}$ -th and $\frac{n}{2} + 1$ -th values.

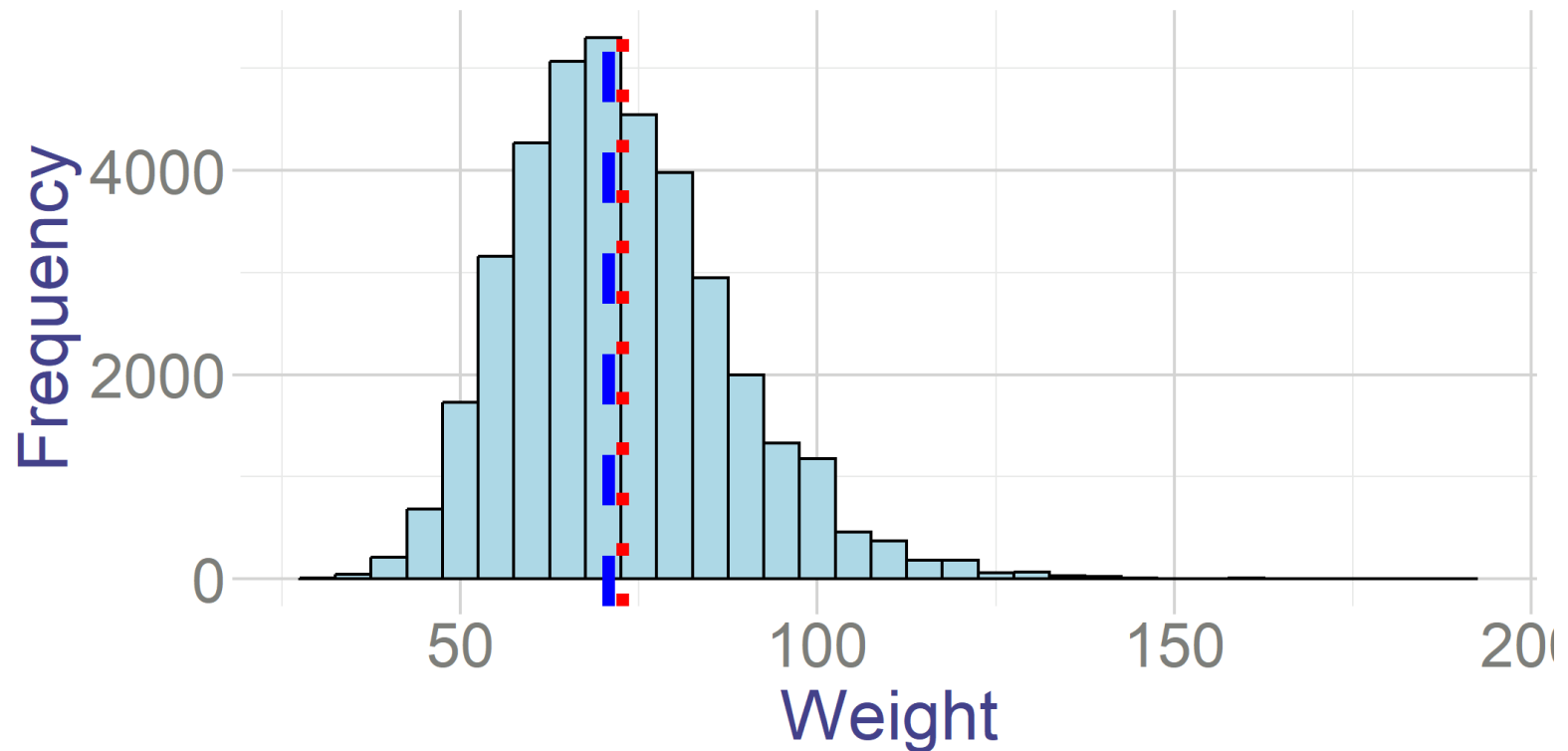
Day	Number of Customers
1	20
2	18
3	25
4	22
5	30
6	21
7	27

The dataset has $n = 7$ (odd) observations, so to find the median:

- Arrange the data in ascending order:
 - 18, 20, 21, 22, 25, 27, 30.
- The median is the $\frac{n+1}{2}$ -th value, which is the 4th value.
- Thus, the median is the 4th value, which is 22.

Let's look at the median weight in our population

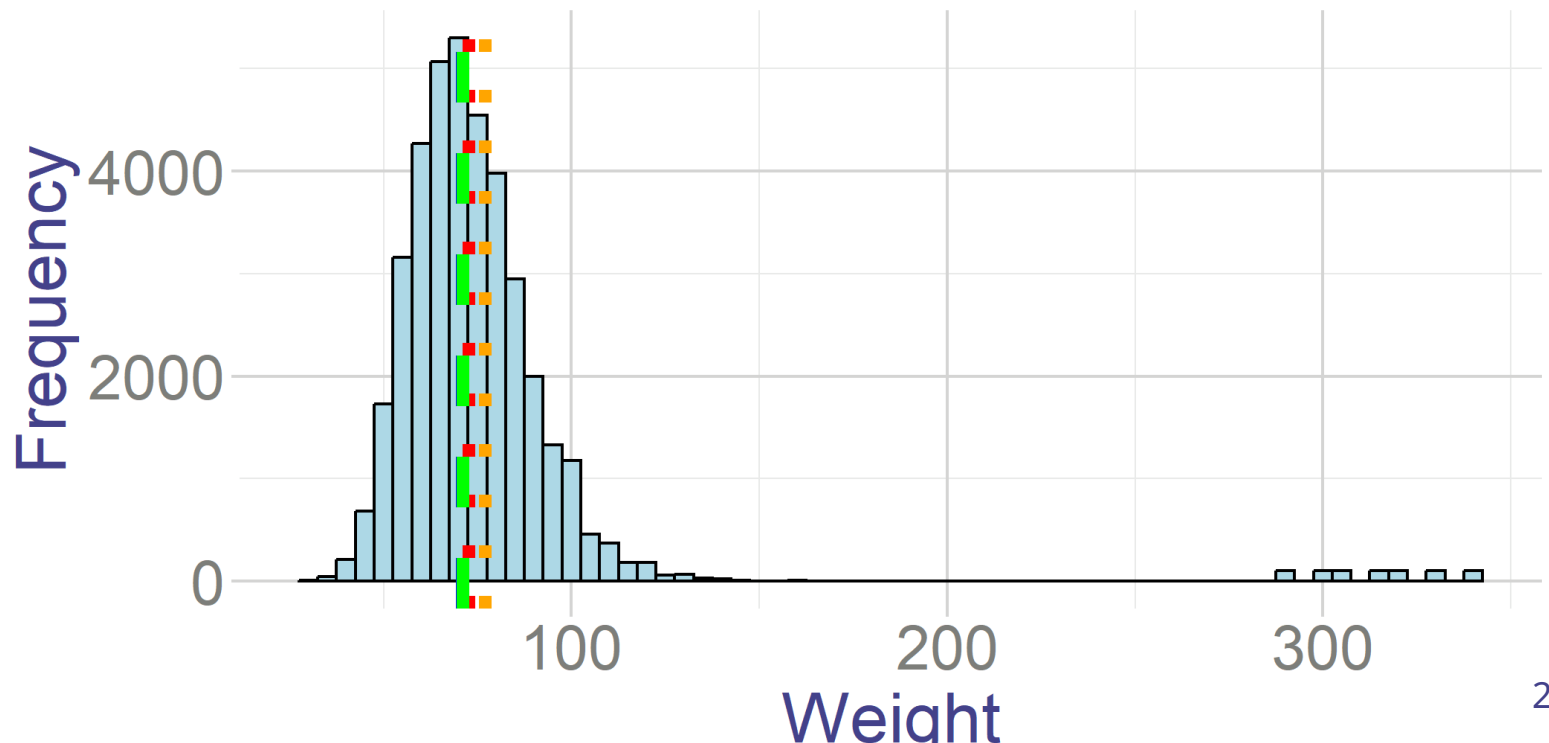
- Mean: 72.66451
- Median: 70.7536



Median and outliers

I added couple of observations on the right tail of the distribution

- Old Mean: 72.66, **New Mean: 77.05**
- Old Median: 70.75, **New Median: 70.95**



Side note on the Mode

Mode is the most frequent value in the data

- Let's look at the distribution of age of people with diabtese

Show entries

Age	n_i	p_i
20	4	0.001
21	2	0
22	4	0.001
23	3	0.001
24	5	0.001
25	7	0.002

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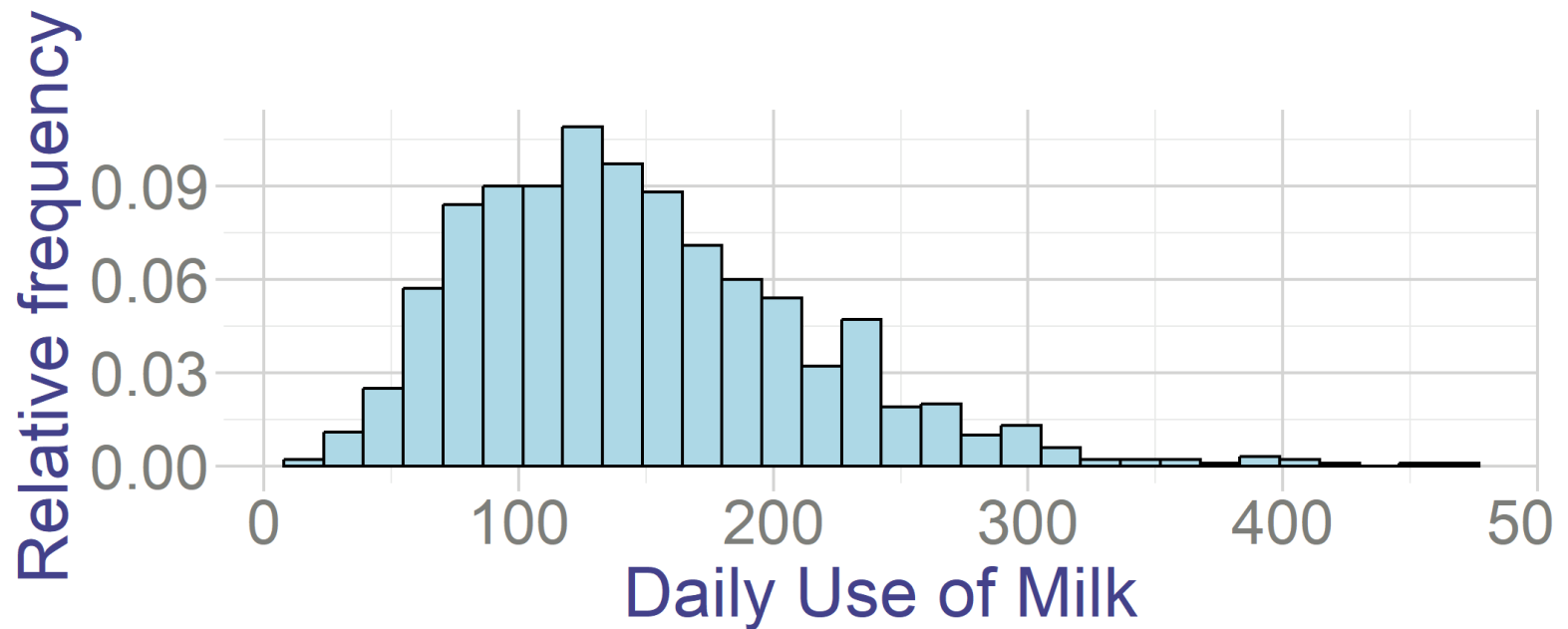
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Mode



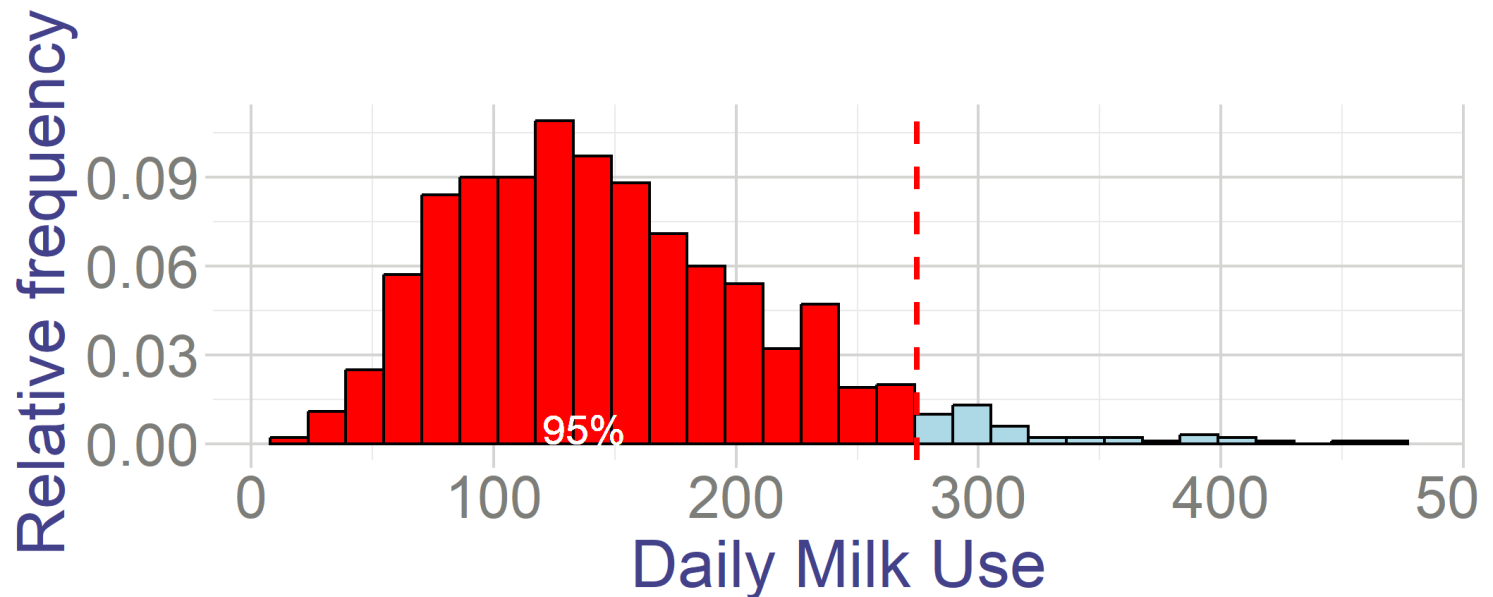
Percentiles

- How much inventory of milk you need to keep in your Starbucks?
- What is the tradeoff of keeping too much vs too little inventory?
- Suppose we want to have enough of milk to cover sales on 95% of days
- To figure it out, let's look at the distribution of the daily use of milk



Percentiles

- Let s_i be the daily sales of milk
- We want to choose amount M , such that $P(s_i \leq M) = 0.95$
- That is, in 95% of days sales are smaller or equal than M



- What is this number?
- It's the 95th percentile of the distribution (274 liters)

Percentiles

- *Percentiles* divide the ordered data into 100 equal parts.
- p th percentile is a value such that $p\%$ of the data are below it
 - v_p is such that $P(x_i \leq v_p) = p$
 - v_{95} is such that $P(x_i \leq v_{95}) = 95\%$

Percentiles

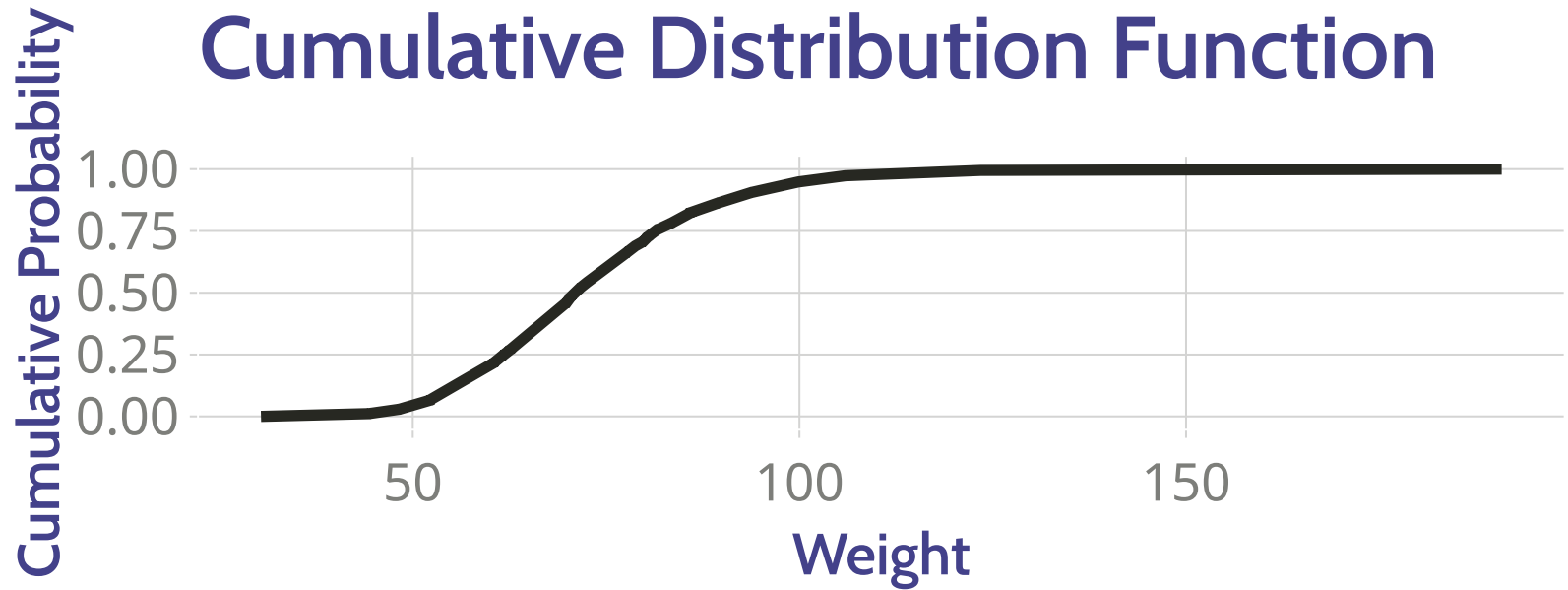
- What is the the height such that 75% of ITAM students are smaller than this height?
- What is the income level such that 25% of people in Mexico earn less than that level?
- What is the age, such that 50% of people die before that age?

How to find it in a sample

1. Arrange the data in ascending order
2. Find which observation corresponds to the relevant percentile
 - Formula: $i = \left(\frac{p}{100}\right) (n + 1)$
 - Example: To find 95th percentile in a sample of 1000 observations we look at $i = \left(\frac{95}{100}\right) (1000 + 1) = 950.95$ observation
3. If it's an integer, value of i th observation is your percentile
4. If it's not, take the average between i th rounded down and i th rounded up
 - In our example it would be the average of 950th and 951th observation

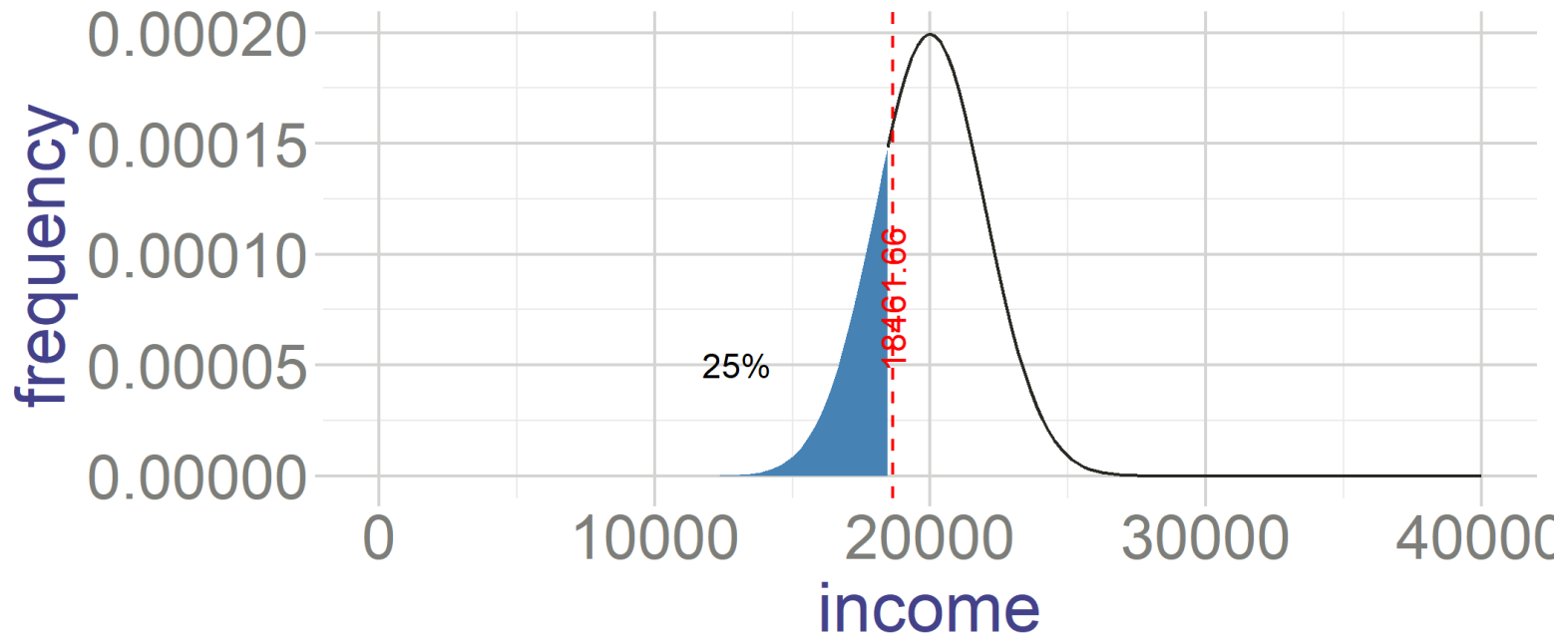
Or use the CDF

- $ECDF(v) = P(x_i \leq v)$

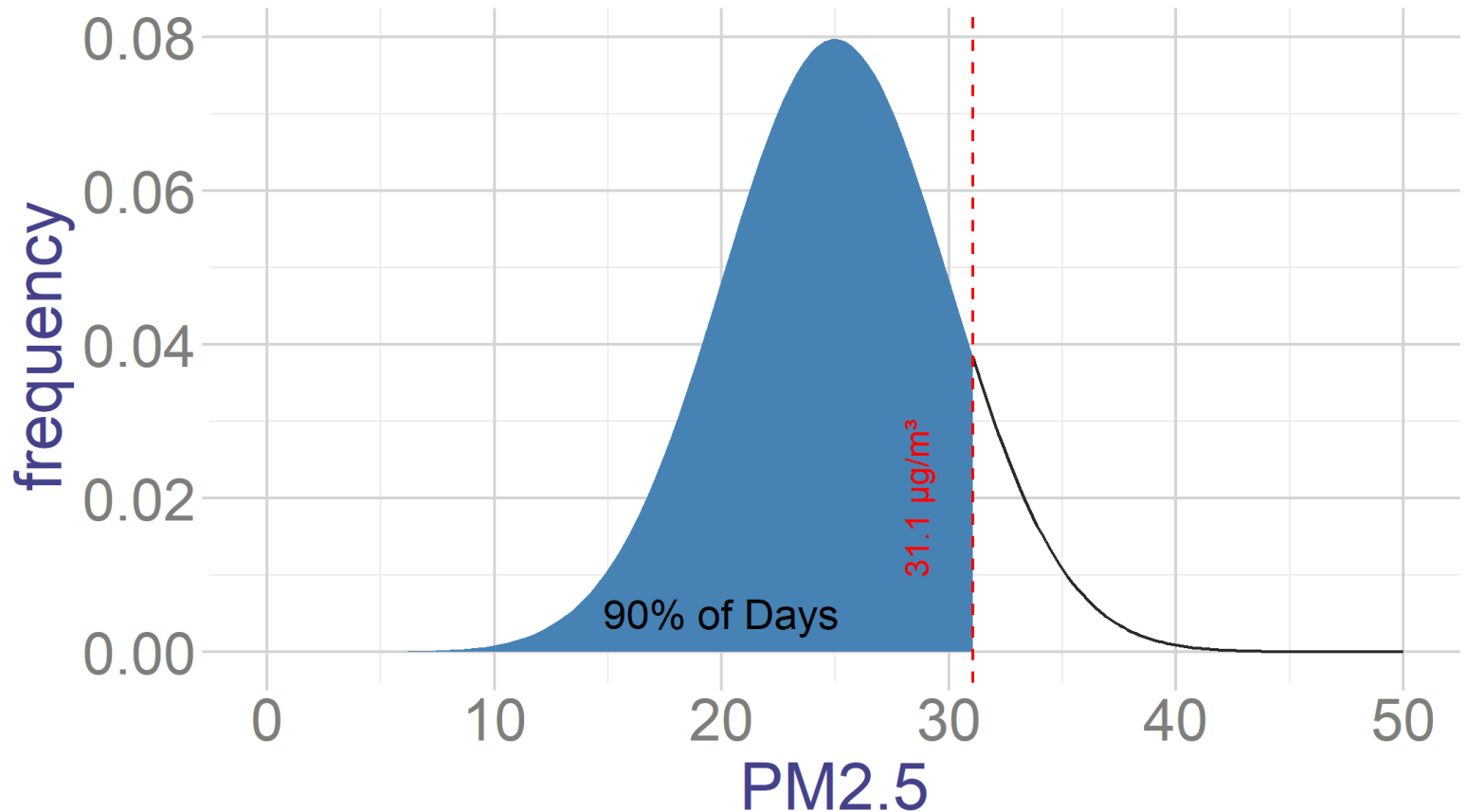


Common values

- **Median** - 50th percentile - half of the values are below the median
- **Quartiles** - 25th, 50th and 75th percentile.
 - How poor is the poorest quartile of the society?
 - Their income is below the 25th percentile



- **Deciles** - 10th, 20th, ... 90th
 - How bad pollution gets in CDMX during top 10% polluted days?
 - During top 10% of polluted days pollution level is larger or than 9th decile.



Example with data

Here is a data on distribution of how many views have various tik-tok videos.

- What is the 1st decile?
- What is the 95th percentile?

Show entries

VideoTitle	Views
TikTok Video 1	172204
TikTok Video 2	9442
TikTok Video 3	37975
TikTok Video 4	56914

Showing 1 to 4 of 200 entries

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- Index for the first decile is: $i = \left(\frac{10}{100}\right) (200 + 1) = 20.1$
 - First decile is the average of the 20th and 21st observation
- Index for the 95th percentile is: $i = \left(\frac{95}{100}\right) (200 + 1) = 190.95$
 - 95th percentile is the average of the at 190th and 191st observation

