Equi-Percentile Normalization Method

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What is Normalization?

Normalization in exams means adjusting the scores of candidates to balance out differences in the difficulty level of different exam sessions or shifts. This ensures fairness for everyone.

Explanation: When an exam is conducted in multiple shifts with the same syllabus, the difficulty level of questions can still vary from one shift to another. Because of this, even candidates with the same ability might score differently depending on the shift they appear in.

To make sure all candidates are judged fairly, a process called statistical normalization is used. This adjusts the marks so that the performance of a candidate reflects their true ability, not the difficulty of the shift they faced.

In simple words, normalization ensures that the marks of candidates are comparable across all shifts. If one shift was tougher, scores from that shift will be adjusted upwards; if another was easier, scores will be adjusted downwards.

Real-Life Example:

Imagine two students, Santos and Sabyasachi, who are equally good at Mathematics.

- Santos appears in Shift 1, where the paper is very tough. She scores 60 marks.
- Sabyasachi appears in Shift 2, where the paper is easier. He scores 70 marks.

Even though Sabyasachi's raw score is higher, both students have the same level of ability. Through normalization, Santos's score will be adjusted upwards, and Sabyasachi's may be adjusted slightly downwards, so their final scores are comparable and fair.

When must we do Normalization?

If there are multiple shifts in exams, then we must do Normalization.

What is Equi-Percentile Method?

Equi-Percentile method is used to Normalize score in an exam across shifts. The method uses "common ground" to equate the raw scores and make them comparable by eliminating the differences in item difficulty across shifts.

The "common ground" refers to Base Shift based which selected based on define guidelines. Base Shift Selection is explained later in the walkthrough. Base shift the focal point to adjust score across other shifts. The Equi-Percentile method ensures comparability of scores across different sessions of any Administration of tests.

Explanation of Equi-Percentile Method Through Example

Given below are the information on two shifts. We are considering Minimum marks as 0 and Maximum marks as 10.

Note: This is a sample data and entire data set taken from a real exam for the purpose of demo. Shift 24S1 has 9660 candidates and 24S2 has 9091 total candidates. The real candidate count in the shift will be used for all calculations.

Definition –

1. **Raw Score** – It is the actual score the candidate has scored.
2. **Frequency (F)** – Number of candidates who have scored the same raw score.
3. **Cumulative Frequency (CF)** – It is the sum of all the frequency from start to the frequency of raw score for which cumulative frequency is calculated.

24S1			24S2		
Raw Score	**Frequency**	**Cumulative Freq**	**Raw Score**	**Frequency**	**Cumulative Freq**
0	26	26	0	42	42
1	126	152	1	170	212
2	340	492	2	438	650
3	697	1189	3	853	1503
4	1094	2283	4	1251	2754
5	1383	3666	5	1504	4258
6	1566	5232	6	1469	5727
7	1473	6705	7	1291	7018
8	1386	8091	8	977	7995
9	942	9033	9	649	8644
10	627	9660	10	447	9091

Step 1 – Calculate the percentile P(x) for each raw score in each shift

$$P(x) = \frac{\text{CF of previous score} + 0.5 * \text{F of present score}}{\text{Total candidate in the shift}} * 100$$

Were,

F is Frequency

CF is Cumulative frequency of each Raw Score.

Note: for the first score the CF of Previous Score will always be Zero as there is no score before it.
The table after calculating P(x) for each Raw Score –

24S1				24S2			
Raw Score	Frequency	Cumulative Freq	P(x)_24S1	Raw Score	Frequency	Cumulative Freq	P(X)_24S2
0	26	26	**0.00**	0	42	42	**0.00**
1	126	152	**0.92**	1	170	212	**1.40**
2	340	492	**3.33**	2	438	650	**4.74**
3	697	1189	**8.70**	3	853	1503	**11.84**
4	1094	2283	**17.97**	4	1251	2754	**23.41**
5	1383	3666	**30.79**	5	1504	4258	**38.57**
6	1566	5232	**46.06**	6	1469	5727	**54.92**
7	1473	6705	**61.79**	7	1291	7018	**70.10**
8	1386	8091	**76.58**	8	977	7995	**82.57**
9	942	9033	**88.63**	9	649	8644	**91.51**
10	627	9660	**96.75**	10	447	9091	**97.54**

Example 1. Showing calculation of Percentile for Raw Score 0 in 24S1 –

Using the formula –

$$P(x) = \frac{\text{CF of previous score} + 0.5 * \text{F of present score}}{\text{Total candidate in the shift}} * 100$$

Raw Score 0 is the first score thus CF (Cumulative Frequency) of Previous Score = 0
F (Frequency) of present score = 26
Total Candidate in Shift = 9660, as mentioned in note that this is a sample data from a larger data set.

Replacing the values in the formula of P(x) we get –

$$P(0)_{24S1} = \frac{0 + 0.5 * 26}{9660} * 100 = 0.13 \approx 0 \text{ (rounded to 0)}$$

Example 2. Showing calculation of Percentile for Raw Score 1 in 24S1 –

Using the formula –

$$\mathbf{P(x) = \frac{CF\ of\ previous\ score + 0.5 * F\ of\ present\ score}{Total\ candidate\ in\ the\ shift} * 100}$$

CF (Cumulative Frequency) of Previous Score = 26
F (Frequency) of present score = 126
Total Candidate in Shift = 9660

Replacing the values in the formula of P(x) we get –

$$\mathbf{P(1)_{24S1} = \frac{26 + 0.5 * 126}{9660} * 100 = 0.92133 \approx 0.92}$$

Step 2 - Identify a Base Shift

The Shift that we will consider as the reference point to normalize scores across other shifts is called Base Shift. An Ideal Base Shift in the Multiple Shift scenario will be the shift where the Mean Raw Score is closest to the Median Raw Score and the score distribution is close to Normal or Symmetrical. For a distribution to be close to Normal the Standard Deviation must be within 2.5 scale.

	24S1	24S2
Mean	6.18	5.73
Median	6	6
SD	2.20	2.21

From the above data,
Difference between Mean Raw Score and Median Raw Score for 24S1 is 0.18.
Difference between Mean Raw Score and Median Raw Score for 24S2 is 0.27.
SD of both shifts is within 2.5
Thus, we consider 24S1 as Base Shift

Step 3 - Calculate Normalized Score called as Equivalent Score

For each Raw Score in each shift –
Percentile (P(x)) for each Raw Score in a Shift (24S2) is matched with the set of percentiles (P(x)) in the Base Shift (24S1). There are two possible outcomes –

Case 1 – A percentile in 24S2 matches with a Percentile in Base Shift (24S1)

Case 2 - The percentile in 24S2 does not match with any Percentile in Base Shift (24S1)

CASE 1 – Percentile P(x) in a Shift to be Normalized matches with a percentile P(x) in Base shift

If a percentile P(x) in Shift to be Normalized matches with a percentile P(x) in Base shift, then the Equivalent Score for the percentile P(x) in Shift to be Normalized is equal to the Raw Score associated with Percentile in Base Shift.

For Example – Consider the table below. Let's take the Percentile P(x) 0 in 24S2. The percentile has a match in Base Shift 24S1. Thus, Raw score for Percentile 0 in Base Shift 24S1 is made as the Equivalent Score for percentile P(x) in 24S2

24S1 (Base Shift)	
Raw Score	**P(x)_24S1_Base**
0	**0**

24S2		
Raw Score	**P(x)_24S2**	**Equivalent Score**
0	**0**	**0**

CASE 2 – Percentile P(x) in a Shift to be Normalized does not matches with any percentile P(x) in Base shift

If the percentile (P(x)) in the Shift under consideration doesn't match any percentile (P(x)) in the Base Shift, then Interpolation Method is used to calculate the Equivalent Score.

In Interpolation Method, if the percentile (P(x)) from a Shift lies between two percentiles in Base Shift then below calculation is performed to calculate the Equivalent Score –

$$\textbf{Equivalent Score} = Y_L + \frac{P(x)_{Shift} - P(x)_{Baseshift}}{P(x)_{UpperBaseShift} - P(x)_{LowerBaseShift}} * (Y_u - Y_L)$$

Were,

$P(x)_{LowBaseShift}$ is the lower percentile in the Base Shift
$P(x)_{UpperBaseShift}$ is the upper percentile in the Base Shift
$P(x)_{Shift}$ is the percentile in Shift such that, **$P(x)_{LowBaseShift} < P(x)_{Shift} < P(x)_{UpperBaseShift}$**
Y_L is the raw score associated with **$P(x)_{LowBaseShift}$**
Y_u is the raw score associated with **$P(x)_{UpperBaseShift}$**

Consider the Example below -

24S1 (Base Shift)	
Raw Score	**P(x)_24S1_Base**
1	**0.92**
2	**3.33**

24S2		
Raw Score	**P(x)_24S2**	**Equivalent Score**
1	**1.40**	
2	**4.74**	

From the table**,** Percentile P(x) for Raw Score 1 in Shift 24S2 is 1.40, it does not match with any of the percentile (P(x)) in the Base Shift 24S1. The value 1.40 lies in between the percentiles (P(x)) 0.92 and 3.33 in the Base Shift 24S1 for the Raw Score 1 and Raw Score 2 in 24S1 respectively.

Thus, we will use interpolation method to generate equivalent score for Raw Score 1 in Shift as follows –

24S1 (Base Shift)	
Raw Score	**P(x)_24S1_ Base**
1	**0.92**
2	**3.33**

24S2						
Raw Score	**P(x)_24S2**	**P(x)_Upper Base Shift**	**P(x)_Low Base Shift**	Y_U	Y_L	**Equivalent Score**
1	**1.40**	3.33	0.92	2	1	**1.20**
2	**4.74**					

Calculation: Equivalent Score for Raw Score 1 in Shift = $1 + \frac{1.40-0.92}{3.33-0.92} * (2-1) = 1.20$

After repeating the process for each raw score in the Shift 24S2 to calculate the Equivalent Score, we get the below table –

24S1 (Base Shift)	
Raw Score	**P(x)_24S1 Base**
0	0.00
1	0.92
2	3.33
3	8.70
4	17.97
5	30.79
6	46.06
7	61.79
8	76.58
9	88.63
10	96.75

24S2						
Raw Score	**P(X)_24S2**	**P(x)_Upper Base Shift**	**P(x)_Low Base Shift**	Y_U	Y_L	**Equivalent Score**
0	**0**	-	-	-	-	**0**
1	**1.40**	3.33	0.92	2	1	**1.20**
2	**4.74**	8.70	3.33	3	2	**2.26**
3	**11.84**	17.97	8.70	4	3	**3.34**
4	**23.41**	30.79	17.97	5	4	**4.42**
5	**38.57**	46.06	30.79	6	5	**5.51**
6	**54.92**	61.79	46.06	7	6	**6.56**
7	**70.10**	76.58	61.79	8	7	**7.56**
8	**82.57**	88.63	76.58	9	8	**8.50**
9	**91.51**	96.75	88.63	10	9	**9.35**
10	**97.54**	100.00	96.75	10	10	**10.00**

Using the above Table, for shift 24S2 candidates raw scores will be replaced with Equivalent Normalized Scores which will be used further for merit listing.

Points to Consider

1. The population size must be 700 or above.
2. Highest Score is the Ceiling Value – i.e. if Highest Score of an Exam is 100, and due to calculation as decimal value is involved, we get a score 100.2 then consider it as 100.
3. Lowest Score is the Floor Score - i.e. if the Lowest Score of an Exam is 0, and due to calculation as decimal value is involved, we get a score -0.2 then consider it as 0.
4. The test design across all exams must be same.
5. Algorithms do not detect any unfair means in exams.