Hanford Part 1

Henry Liu

The Problem

In an article taken from the Journal of Environmental Health, May-June 1965, Volume 27, Number 6, pages 883-897, author Robert Fadely explains that the Atomic Energy Plant in Hanford, Washington has been a plutonium production facility since the Second World War. Some of the waste have been stored underground in the same area. Radioactive waste has been seeping into the Columbia River, and eight Oregon counties and the city of Portland have been exposed to radioactive contamination. The table below lists the number of cancer deaths per 100,000 residents for Portland and these counties. The table also includes an index of exposure that measures the proximity of the residents to the contamination. The index is based on the assumption that city or county exposure is directly proportional to river frontage and inversely proportional both to the distance from Hanford, WA site and to the square of the county's or city's average distance from the river.

Location	Umatilla	Morrow	Gilliam	Sherman	Wasco	Hood River	Portland	Columbia	Clatsop
Index	2.5	2.6	3.4	1.3	1.6	3.8	11.6	6.4	8.3
Deaths	147	130	130	114	138	162	208	178	210

The Process

Formatting the Data

```
l1 = {2.5, 2.6, 3.4, 1.3, 1.6, 3.8, 11.6, 6.4, 8.3};
l2 = {147, 130, 130, 114, 138, 162, 208, 178, 210};

l3 = Transpose[{l1, l2}]; (* Actual Values *)
l4 = Insert[l3, {"Index", "Deaths"}, 1]; (* List for grid display *)

Grid[l4, Frame → All]
```

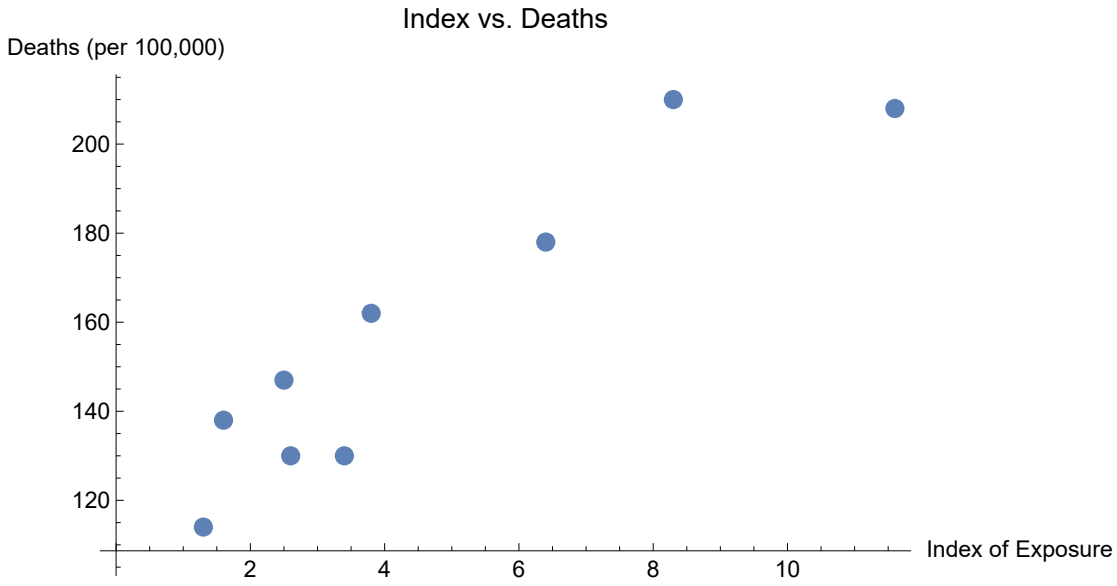
Out[•]=

Index	Deaths
2.5	147
2.6	130
3.4	130
1.3	114
1.6	138
3.8	162
11.6	208
6.4	178
8.3	210

Plotting the Data

In[ ]:=
```
Show[ListPlot[l3, PlotStyle → {AbsolutePointSize[10]}],
 AxesLabel → {"Index of Exposure", "Deaths (per 100,000)"},
 PlotLabel → "Index vs. Deaths", ImageSize → Large, LabelStyle → {12}]
```

Out[ ]=



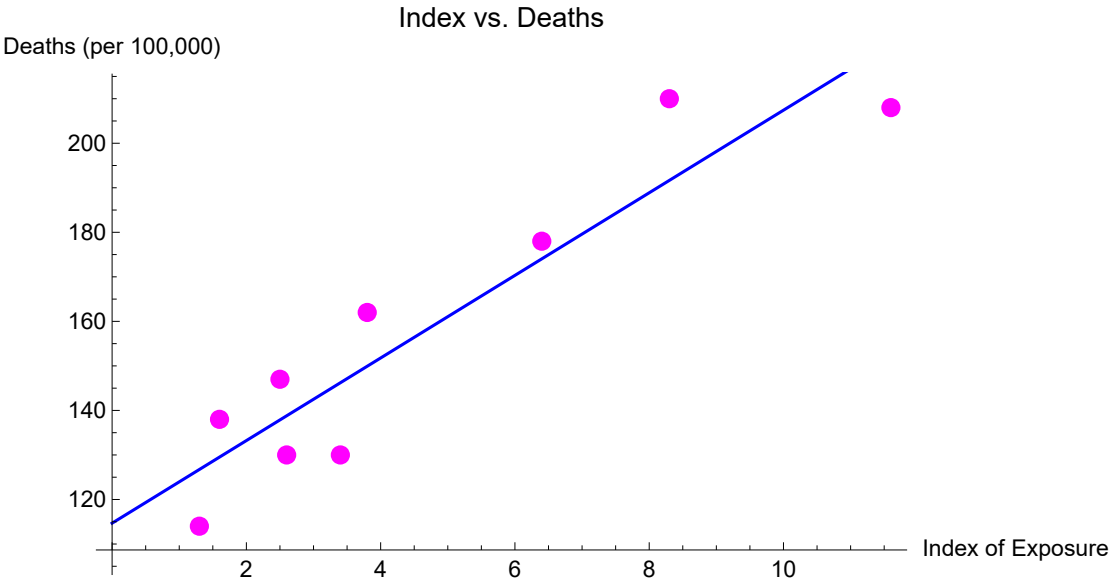
Finding the Least Squares Line of Best Fit

```
vA = Sum[(l2[[i]])^2, {i, 9}];

vB = Sum[(l1[[i]])^2, {i, 9}];

vC = Sum[l1[[i]], {i, 9}];

vD = Sum[(l1[[i]] * l2[[i]]), {i, 9}];

vE = Sum[l2[[i]], {i, 9}];


m = (9 * vD - vE * vC) / (9 * vB - vC^2);
b = (vE - m * vC) / 9;


f[x_] = m * x + b (* Least squares line of best fit *)
```

Out[ ]= 114.682 + 9.27386 x

```
In[ ]:= Show[ListPlot[l3, PlotStyle → {AbsolutePointSize[10], Magenta}],
 Plot[f[x], {x, 0, 200}, PlotStyle → {Blue}], PlotLabel → "Index vs. Deaths",
 AxesLabel → {"Index of Exposure", "Deaths (per 100,000)"},
 ImageSize → Large, LabelStyle → {12}]
```

Out[ ]=



```
l5 = Table[f[i], {i, {l1}}];
l5 = l5[[1]];

l6 = Transpose[{l1, l5}]; (* Predicted values *)

l7 = Transpose[{l1, l2, l5}]; (* Values for grid *)
l7 = Insert[l7, {"Index", "Actual Deaths", "Predicted Deaths"}, 1];

Grid[l7, Frame → All]
```

Out[•]=

Index	Actual Deaths	Predicted Deaths
2.5	147	137.866
2.6	130	138.794
3.4	130	146.213
1.3	114	126.738
1.6	138	129.52
3.8	162	149.922
11.6	208	222.258
6.4	178	174.034
8.3	210	191.655

Finding Residual Values

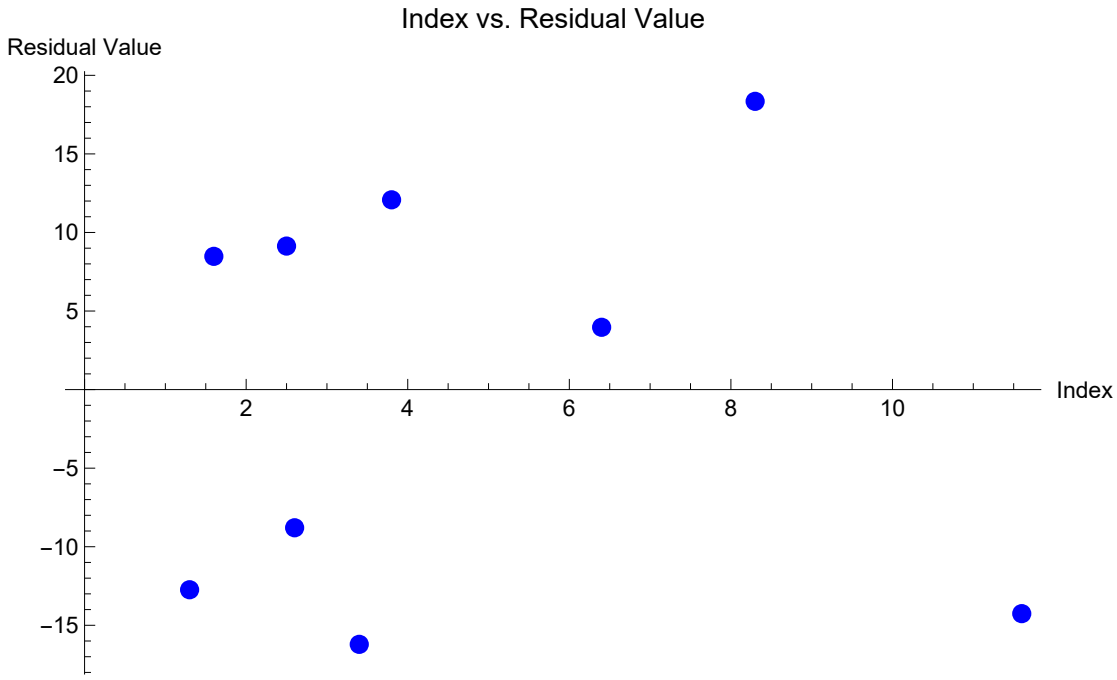
```
l8 = l2 - l5; (* Residual values *)
l9 = Transpose[{l1, l8}]; (* Residual value points *)
l10 = Insert[l9, {"Index", "Residual Value"}, 1]; (* Values for grid *)

Grid[l10, Frame → All]
```

Out[•]=

Index	Residual Value
2.5	9.13371
2.6	−8.79367
3.4	−16.2128
1.3	−12.7376
1.6	8.48019
3.8	12.0777
11.6	−14.2585
6.4	3.96564
8.3	18.3453

In[•]:=
```
Show[ListPlot[l9, PlotStyle → {AbsolutePointSize[10], Blue}],
 ImageSize → Large, AxesLabel → {"Index", "Residual Value"}, LabelStyle → {12},
 PlotLabel → "Index vs. Residual Value" ](* Graph of residual values*)
```

Out[•]=




```
resiSum = Total[l8] (* Sum of residuals *)
```

Out[•]= 0.

Results

Least Squares Line of Best Fit

The line of best fit was found to be f[x] = 114.68162624887519 + 9.273864186990922x

```
Grid[l7, Frame → All] (* Table of indexes, actual deaths,
and deaths predicted the line of best fit *)

Show[ListPlot[l3, PlotStyle → {AbsolutePointSize[10]}],
 AxesLabel → {"Index of Exposure", "Deaths (per 100,000)"}, PlotLabel → "Index vs. Deaths",
 ImageSize → Large, LabelStyle → {12}](* Data given from problem *)

Show[ListPlot[l3, PlotStyle → {AbsolutePointSize[10], Magenta}],
 Plot[f[x], {x, 0, 200}, PlotStyle → {Blue}], PlotLabel → "Index vs. Deaths",
 AxesLabel → {"Index of Exposure", "Deaths (per 100,000)"},
 ImageSize → Large, LabelStyle → {12}](* Least squares line of best fit *)
```

Out[•]=

Index	Actual Deaths	Predicted Deaths
2.5	147	137.866
2.6	130	138.794
3.4	130	146.213
1.3	114	126.738
1.6	138	129.52
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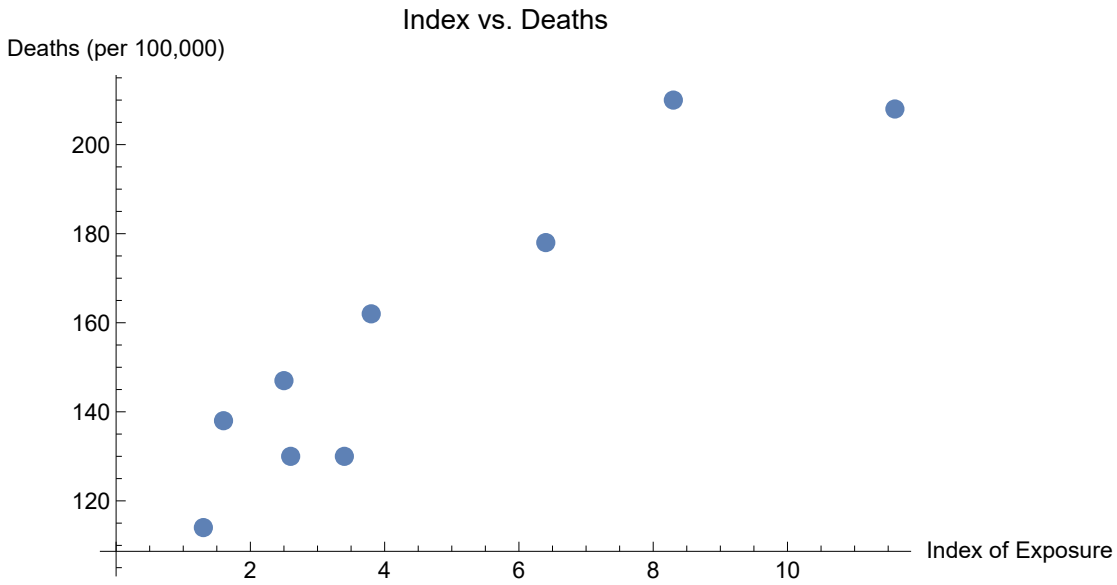
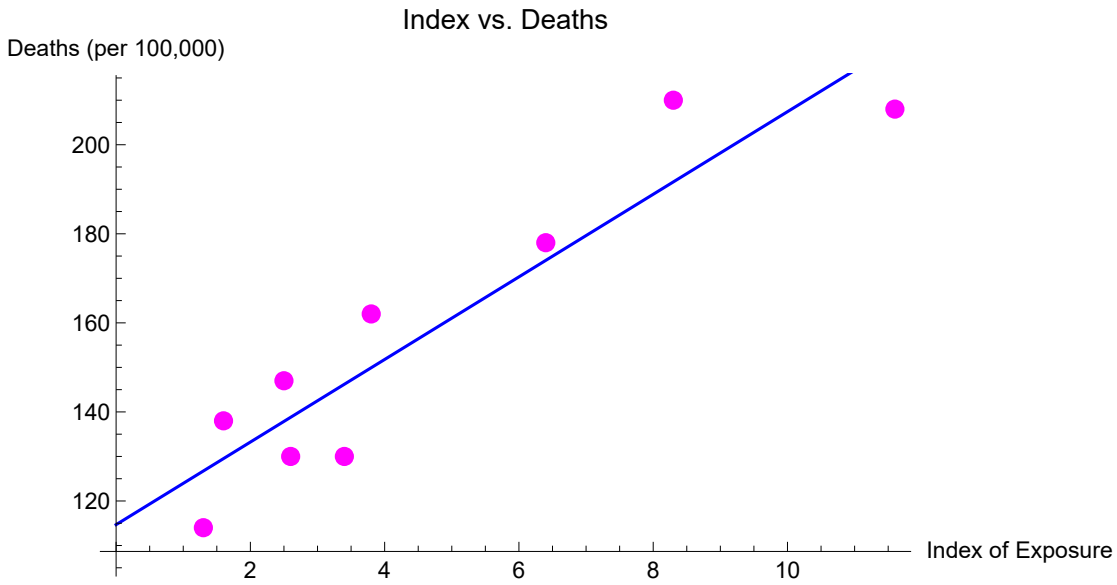
11.6	208	222.258
6.4	178	174.034
8.3	210	191.655

Out[ ]=


Index vs. Deaths
Deaths (per 100,000)
200
180
160
140
120
2
4
6
8
10
Index of Exposure

Out[ ]=


Index vs. Deaths
Deaths (per 100,000)
200
180
160
140
120
2
4
6
8
10
Index of Exposure

Residual Values and Sum

Sum of residual values : 0

```
Grid[l10, Frame → All] (* Table of indexes and residual values *)

Show[ListPlot[l9, PlotStyle → {AbsolutePointSize[10], Blue}],
 ImageSize → Large, AxesLabel → {"Index", "Residual Value"}, LabelStyle → {12},
 PlotLabel → "Index vs. Residual Value" ] (* Residual values *)
```

Out[•]=

Index	Residual Value
2.5	9.13371
2.6	−8.79367
3.4	−16.2128
1.3	−12.7376
1.6	8.48019
3.8	12.0777
11.6	−14.2585
6.4	3.96564
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Out[•]=