

Path Analysis Step by Step Using Excel

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Abstract

Quantifying the contribution of causal variables to a targeted effect variable directly and indirectly through other variables has always been the layer that researchers seldom examine. Path analysis method may be a natural extension to regression analysis where researchers may be able to quantitatively examine the direct contributions to the effect variable and the indirect effects through other variable to the effect variable. Researchers are sometimes forced to stop their investigation at regression analysis level even when their model reports highly positive fit but could not find or explain any direct positive significant contribution from any of the causal variables in the system. It is a decision support tool that helps researchers determine the contribution of each variable to the effect and each variable via other variables to that effect. This paper gives us a step by step approach to doing path analysis using the Microsoft office Excel software. A tool most common to PC's based on Microsoft windows operating systems and its users.

Keywords: Path analysis, path coefficient, causal factors, effect variables, multiple regressions, standardized variables, direct path coefficient, indirect path coefficient.

Introduction

The path coefficient method was pioneered by Prof. Sewall Wright (1921, 1960). The work was only related to population genetics at first. Now it is being applied in all works of life.

Path Analysis extends multiple regression analysis, but while regression gives the best or closest prediction of the response variable based on the given causal factors by the method of least squares, path analysis goes further by providing probable interpretation of the relationships between and within the contributing causal factors to the observed effects.

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + U \quad (\text{eq. 1})$$

The case of multiple regression in the equation above looks at a single response variable as a function of several causal / explanatory variables with the assumptions that values of variables are random, normally distributed and that the causal variables are independently contributing to the response variable.

$$p_{01} X_1 + p_{02} X_2 + p_{03} X_3 + U = Y \quad (\text{eq. 2})$$

Path analysis (eq. 2) on the other hand, examines several explanatory variables as a function of the response variable of interest. It assumes that causal factors are corre-

lating to contribute to the response variable. In other words causal factors are not acting independently.

Methodology

Any computer that will accommodate the windows operating system that runs the Microsoft office Excel should be adequate for the practical demonstration of the ways to do path analysis.

The data for our analysis is taken from (Li, 1975). This data is standardized before a regression analysis is carried out using excel. Regression on a standardized variable/s gives partial regression coefficients unlike regression on non-standardized variables that gives concrete regression coefficients.

This contains one dependent variable Y and four independent variables X1...X4 (13 cases), applying the equation $x^* = (x-m)/sd$ to the raw data on the left results in the standardized set on the right.

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Table 1:

Y	X ₁	X ₂	X ₃	X ₄	Y	X ₁	X ₂	X ₃	X ₄
78.5	7	26	6	60	-1.1249	-0.0785	-1.4237	-0.9007	1.7923
74.3	1	29	15	52	-1.4041	-1.0984	-1.2309	0.5044	1.3144
104.3	11	56	8	20	0.5901	0.6015	0.5042	-0.5885	-0.5974
87.6	11	31	8	47	-0.5200	0.6015	-1.1024	-0.5885	1.0156
95.9	7	52	6	33	0.0317	-0.0785	0.2472	-0.9007	0.1792
109.2	11	55	9	22	0.9158	0.6015	0.4400	-0.4323	-0.4779
102.7	3	71	17	6	0.4837	-0.7584	1.4682	0.8167	-1.4338
72.5	1	31	22	44	-1.5238	-1.0984	-1.1024	1.5973	0.8364
93.1	2	54	18	22	-0.1544	-0.9284	0.3757	0.9728	-0.4779
115.9	21	47	4	26	1.3612	2.3015	-0.0741	-1.2130	-0.2390
83.8	1	40	23	34	-0.7726	-1.0984	-0.5240	1.7534	0.2390
113.3	11	66	9	12	1.1883	0.6015	1.1469	-0.4323	-1.0754
109.4	10	68	8	12	0.9291	0.4315	1.2754	-0.5885	-1.0754

Mean	95.4231	7.4615	48.1538	11.7692	30.00	0	0	0	0	0
Std	15.0437	5.8824	15.5609	6.4051	16.7382	1	1	1	1	1

Table 2: Regression analysis on non-standardized variable.

	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	4	2667.90	666.975	111.48	<.001
Residual	8	47.86	5.983		
Total	12	2715.76	226.314		
Change	-4	-2667.90	666.975	111.48	<.001

Percentage variance accounted for 97.4
 Standard error of observations is estimated to be 2.45
 *** Estimates of regression coefficients ***

	estimate	s.e.	t(8)	t pr.
Constant	62.4	70.1	0.89	0.399
X1	1.551	0.745	2.08	0.071
X2	0.510	0.724	0.70	0.501
X3	0.102	0.755	0.14	0.896
X4	-0.144	0.709	-0.20	0.844

Table 3: Regression analysis on standardized variable.

SUMMARY OUTPUT						
Regression Statistics						
Multiple R		0.991148637				
R Square		0.98237562				
Adjusted R Square		0.973563431				
Standard Error		0.162593508				
Observations		13				
ANOVA						
	df	SS	MS	F	Significance F	
Regression	4	11.78854	2.947136	111.4792	4.76E-07	
Residual	8	0.211493	0.026437			
Total	12	12.00004				
Coefficients						
	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	
Intercept	-7.27325E-06	0.045095	-0.00016	0.999875	-0.104	0.103983
X1	0.606513438	0.291221	2.08266	0.070822	-0.06504	1.27807
X2	0.527707059	0.748672	0.704858	0.500901	-1.19873	2.254148
X3	0.043389586	0.32133	0.135031	0.895923	-0.6976	0.784378
X4	-0.160287849	0.788919	-0.20317	0.844071	-1.97954	1.658963

Direct Path Coefficient

Regression analysis on a set of standardized variables results in partial regression coefficients. Partial regression coefficients are in fact another name for direct path coefficients.

Assuming we have a set of five variables Y, X₁, X₂, X₃ and X₄

$\sigma X_1/\sigma Y = 'p_1'$, the path coefficient from X₁ to Y

$\sigma X_2/\sigma Y = 'p_2'$, the path coefficient from X₂ to Y

$\sigma X_3/\sigma Y = 'p_3'$, the path coefficient from X₃ to Y

$\sigma X_4/\sigma Y = 'p_4'$, the path coefficient from X₄ to Y

The indirect contributions of X₁ to Y will include X₁ to Y through X₂, X₃ and X₄. The same applies to X₂, X₃ and X₄

Standardizing variables in Ms Excel

Consider the example in the methodology section of this paper. The initial values of the five variables are transformed to generate the standardized version by first finding the mean and standard deviation of each unstandardized variable in Excel (I am assuming that my audience can do this) and then for each variable, creating a corresponding column to hold the standardized values of the variables by applying this formula $x^* = (x-m)/sd$. An example is to take each value x of big Y, subtracting the mean obtained for big Y and then divide the result by the standard deviation (sd) obtained for big Y. Do this repeatedly until all 13 cases of the big Y values are exhausted. Then you have a set of standardized values for Y.

These values can then be placed in a corresponding field for small y. Repeat the same procedure for all other variables in the equation/dataset and the whole dataset is transformed. This procedure is simpler if you are familiar with how to include Excel functions in your spread sheets columns. Excel will automatically calculate the values and place it in the column you indicate for the result for each variable →

$$(x^* = (x-m)/sd)$$

In practice

The first step is to open your excel data file like in sample frame 1 below, highlight the first data column as in the frame. Observe the last line giving the initial statistics (Average, Count and sum). These basic statistics will form the base for calculating the standard deviation and your standardization process.

Repeat the same for all the variables in your excel file and obtain the relevant basic statistics that will support your standardization.

Raw unstandardized data in excel table

	Y	X1	X2	X3	X4
1					
2	78.5	7	26	6	60
3	74.3	1	29	15	52
4	104.3	11	56	8	20
5	87.6	11	31	8	47
6	95.9	7	52	6	33
7	109.2	11	55	9	22
8	102.7	3	71	17	6
9	72.5	1	31	22	44
10	93.1	2	54	18	22
11	115.9	21	47	4	26
12	83.8	1	40	23	34
13	113.3	11	66	9	12
14	109.4	10	68	8	12

Sample Frame 1

Excel functions to generate MEAN and StDev

	Y	X1	X2	X3	X4	
1						
2	78.5	7	26	6	60	
3	74.3	1	29	15	52	
4	104.3	11	56	8	20	
5	87.6	11	31	8	47	
6	95.9	7	52	6	33	
7	109.2	11	55	9	22	
8	102.7	3	71	17	6	
9	72.5	1	31	22	44	
10	93.1	2	54	18	22	
11	115.9	21	47	4	26	
12	83.8	1	40	23	34	
13	113.3	11	66	9	12	
14	109.4	10	68	8	12	
16	MEAN	95.42308	7.461538	48.15385	11.76923	30
17	STDEV	15.04372	5.882394	15.56088	6.405126	16.73818

Sample Frame 2

As an alternative, you can insert excel functions into whatever positions you desire to place your basic statistics like in sample frame 2. In this case I had placed the desired statistics below the columns of raw data. This is more relevant as I can then reference each of these cells relative to my subsequent calculations. The example in sample frame 2 highlights cell B17 where I want to place the value calculated from my function placed at the point of the arrow above, it calculates the standard deviation of the values in cell B2 to B14.

The result of that calculation is placed in cell B17 (15.04372 for Y). The same was repeated for X1 (C17), X2(D17), X3(E17), and X4(F17). All that is required is to change the reference positions of the cells in the function below the arrow to B, C, D, E, & F accordingly. The difference between this and calculating for the mean is instead of STDEV(B2:B14), you have AVERAGE(B2:B14) placed

as the function.

Now that you are introduced to the excel function, the process of standardizing your raw values should become easier. Now consider the $(x^* = (x-m)/sd)$ for standardization. Since you have the mean and standard deviation for the variables in question, you can do your calculation by brute force or do it using the Excel function STANDARDIZE. It takes 3 arguments, the value of the variable to standardize, its mean and its standard deviation. As an example to standardize the first value of Y, you will insert into the function box =STANDARDIZE(B2,B16,B17), or better still =STANDARDIZE(B2,95.423,15.044) using the later in the first cell to be calculated will allow you to drag the formula down for all cells under Y variable since the mean and STDEV is common for all the values of Y to generate the series of standardized values.

	Y	X1	X2	X3	X4	H
1						
2	78.5	7	26	6	60	-1.1249
3	74.3	1	29	15	52	-1.40408
4	104.3	11	56	8	20	0.590069
5	87.6	11	31	8	47	-0.52001
6	95.9	7	52	6	33	0.031707
7	109.2	11	55	9	22	0.91578
8	102.7	3	71	17	6	0.483714
9	72.5	1	31	22	44	-1.52373
10	93.1	2	54	18	22	-0.15441
11	115.9	21	47	4	26	1.361141
12	83.8	1	40	23	34	-0.7726
13	113.3	11	66	9	12	1.188314
14	109.4	10	68	8	12	0.929075
16	MEAN	95.42308	7.461538	48.15385	11.76923	30
17	STDEV	15.04372	5.882394	15.56088	6.405126	16.73818

Sample Frame 3

Standardizing values for Y,

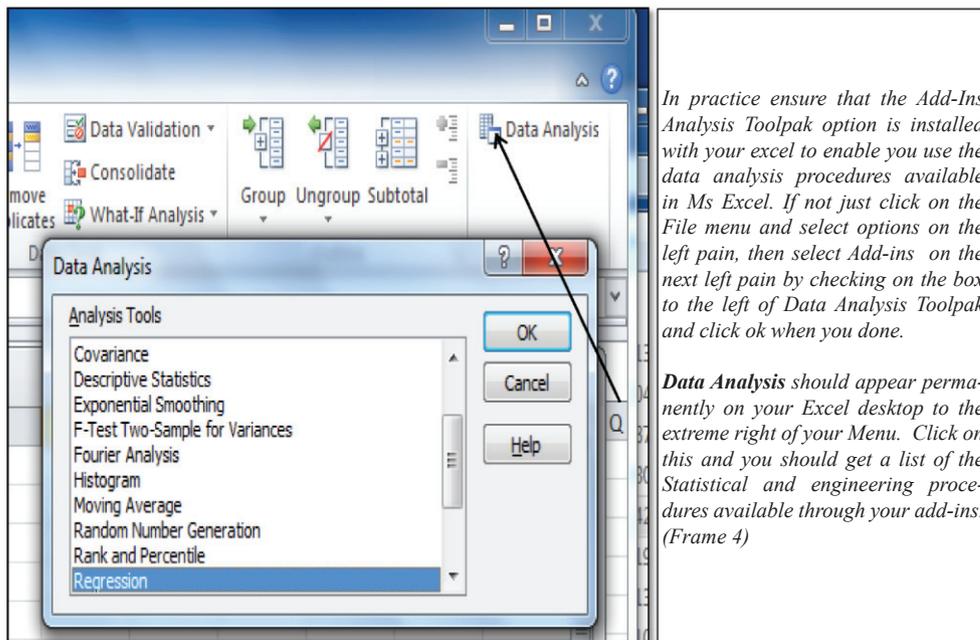
Note: The function at the arrow point, the function was dragged down the column to generate the standardized series for Y. The same can be repeated to generate for X1, X2, X3, & X4

Calculating Direct Path Coefficient in Ms Excel

Having obtained your series of standardized values for the 5 variables Y, X1, X2, X3, & X4 you now have a table that looks like the one on our methodology section. All that is required at this point is to carry out regression analysis on the new standardized variables specifying Y as

the Dependent variable and the X's as your independent variables.

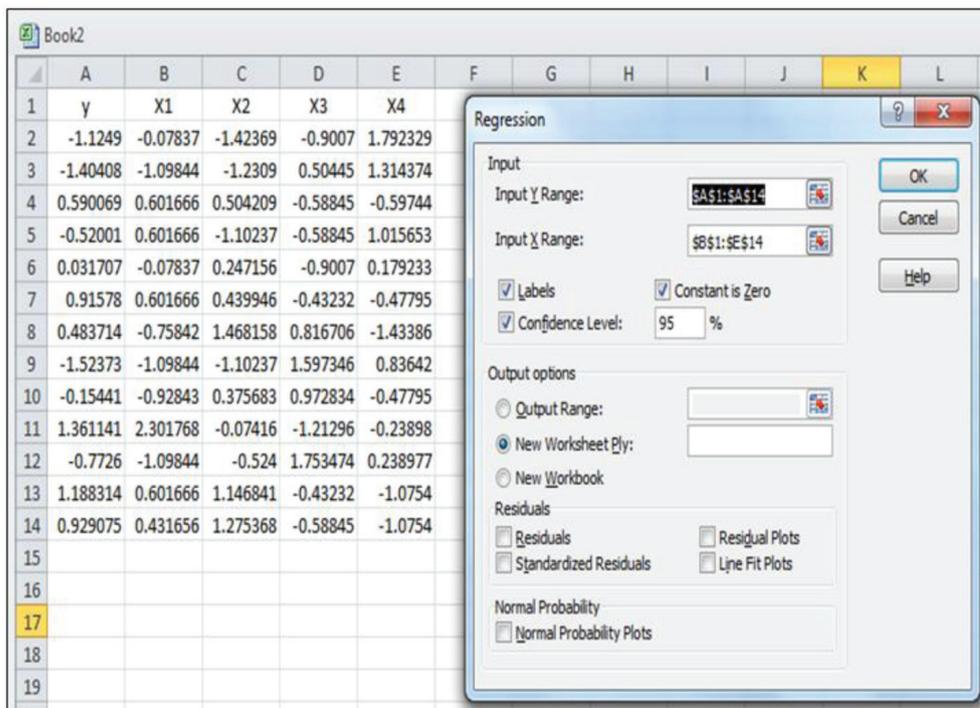
The resultant coefficients for X1, X2, X3 and X4 are called partial regression Coefficients in other words, the direct contribution of the X's individually to the Dependent variable Y. This is the Direct Path Coefficients of the causal factors to the effect variable.



In practice ensure that the Add-Ins Analysis Toolpak option is installed with your excel to enable you use the data analysis procedures available in Ms Excel. If not just click on the File menu and select options on the left pain, then select Add-ins on the next left pain by checking on the box to the left of Data Analysis Toolpak and click ok when you done.

Data Analysis should appear permanently on your Excel desktop to the extreme right of your Menu. Click on this and you should get a list of the Statistical and engineering procedures available through your add-ins. (Frame 4)

Sample Frame 4



Sample Frame 5: Parameter Selection for Regression Analysis

When you click on regression as the procedure you intend to use, you should get what looks like frame 5 above. To the left are your standardized variables and to the right is where you chose your regression parameters and the range of the cells for your Dependent (Y) and Independent variables (X's). Note that if you check labels as in the box, it means that the first row of your data will be used as labels. When you are done selecting your parameters and defining your data range, click OK to get your output displayed. An output similar to the one in methodology section for standardized variables should be displayed.

Calculating Indirect Path Coefficients in Ms Excel

It is now a matter of multiplication and substitution to calculate the indirect path coefficients and a number of ways can be employed. But going the Excel way will be our focus. The only complement to our endeavour is to obtain the correlations matrix for the variables included in our equations and these I hope will be easy to our readers. Just in case it is not, I will explain how these are obtained for our sample data through Excel.

Just refer back to the stage of choosing regression for your analysis of the standardized variables, now instead of regression choose Correlation and specify the parameters and the range for your data as you did for regression, do not forget to check that the first row contains labels. When you are done, click OK, a table like

Journal of Technical Science and Technologies the one below (Table 4) should be generated for you. The next step towards obtaining our indirect path coefficients is to bring forth our direct path coefficients generated earlier (Table 5). With these two tables (Table 4 and Table 5), you can generate a table of indirect contributions for all variables in the equation.

Table 4: Correlation matrix.

	y	X1	X2	X3	X4
y	1				
X1	0.730717	1			
X2	0.816253	0.228579	1		
X3	-0.53467	-0.82413	-0.13924	1	
X4	-0.82131	-0.24545	-0.97295	0.029537	1

From our regression analysis we obtained the table below for direct path coefficients

Table 5: Partial Regression Coefficients

Intercept	-.27325E-06
X1	0.606513438
X2	0.527707059
X3	0.043389586
X4	-0.160287849

Path analysis can be referred to as the process of splitting correlation coefficients into its component parts. It could be defined as the ratio of the standard deviation of the effect due to a given cause to the total standard deviation of the effect (direct path coefficient).

If Y is the effect and X₁ is the cause, the path coefficient for the path from cause X₁ to the effect $Y = \sigma X_1 / \sigma Y_1$ (eq. 3)

As earlier mentioned under direct path coefficients calculation $\sigma X_1 / \sigma Y = 'p_1'$, the path coefficient from X₁ to Y

The indirect contributions of X₁ to Y will include X₁ through X₂, X₃ and X₄. The same applies to X₂, X₃ and X₄. The equation below illustrates the splitting process for a 3 factor causal variables with one effect variable Y

$$r(X_1, Y) = a+r(X_1, X_2) b+r(X_1, X_3)c$$

$$r(X_2, Y) = r(X_2, X_1) a+b+r(X_2, X_3)c$$

$$r(X_3, Y) = r(X_3, X_1) a+r(X_3, X_2)b+c.....(eq. 4)$$

The above equations shows that we may partition each of the correlation from X₁ to Y, X₂ to Y, X₃ to Y into their component paths, i.e in the case of X₁ to Y,= from our sample data.

- (1) due to direct effect of X₁ on Y
- (2) due to indirect effect of X₁ on Y via X₂,
- (3) due to indirect effect of X₁ on Y via X₃ and
- (4) due to indirect effect of X₁ on Y via X₄

$$P_{x_2 Y_{12}} = (0.5277 * 0.2286) = 0.1206$$

$$P_{x_3 Y_{13}} = (0.0434 * -0.8241) = -0.0358$$

$$P_{x_4 Y_{14}} = (-0.1603 * -0.2454) = 0.0393$$

To achieve this on an excel template from our earlier practice should be easy, since all we have to do is set up two columns corresponding to the Direct path coefficients and correlation matrix of respective cause and effect variables and put in a function to multiply the values in the two columns to generate the indirect coefficients.

A sample run from a custom path analysis program using the previous sample data's regression coefficients

(1) If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then correlation explains the true relationship.

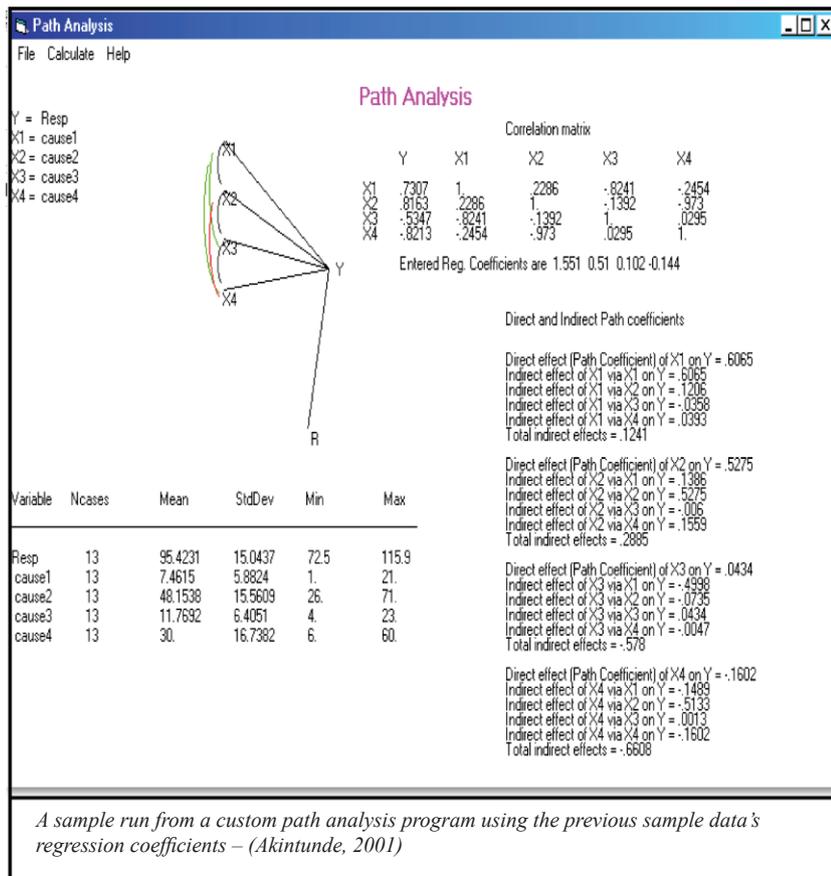
(2) If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be the cause of correlation. In such cases, the indi-

rect causal factors are to be considered.

(3) The correlation coefficient may be negative but the direct effect is positive and high. In these circumstances, a way to selectively drop the undesirable indirect effects will have to be introduced. (Singh; Chaudhary, 1977)

(4) The residual effect determines how best the causal factors account for variability of the dependent variable. If the residual accounts for a large portion of the variability in the dependent variable, it then means that other causal variables have to be brought into the study as those being considered are not the causal factors directly responsible for the effect.

(5) A way to cross check / validate your result is to add the direct path coefficient of a particular causal factor to its indirect effects; the result should be equal to the correlation coefficient between that causal factor and the response variable. There may be some rounding errors and these should be apparent. If your correlation coefficient is not equal to the total indirect + direct path coefficient, you may want to double check on your data and your multiple regression coefficients.



Conclusion

Successful prediction of consequences / effects depends on the recognition of the causes / factors contributing to the system being predicted.

Many researchers stop shut at correlation coefficients because the regression statistics they obtain from their data looks unreal and they could not find alternative explanation to the results. But knowing what to do and how to do it even with a simple tool like Ms. Excel when such opportunity presents itself will enable researchers obtain further explanations on causes and effect variables and may therefore encourage further research.

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