Improved Cost Planning for Solid Waste Management in Developing Countries

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Abstract

The need for improved estimation and planning methods for solid waste management (SWM) is particularly strong in emerging economies such as India, China and Phillipines where problems are severe, expectations for improvements are high, but finances are constrained. An attempt has been made to relate the average costs of SWM using 200x, NIUA data from … municipalities in India. The data were analysed for different population ranges. The data present high scatter but indicate no clear correlation between per ton or per capita costs and population, indicating no clear economy-of-scale.. Stepwise multiple regression involving … predictor variables was conducted on costs to detect any statistically significant correlations. It can be concluded that average costs on either a per ton or per capita basis are most influenced by the total number of staff employed in municipalities. This result is expected because SWM is a highly labour intensive activity in India. The analysis, although preliminary, can be useful as a planning tool for SW managers.

Introduction

Improper planning of finances for the solid waste (SW) sector affects the quality of the service provided. Provision of funds for solid waste management particularly in developing countries is commonly observed to be made on an ad-hoc basis. A closer look at the available SWM literature focusing on developing countries indicates that little or no effort has been made to study the economic aspects of this topic. Governments in these countries are under immense pressure from residents to upgrade solid waste facilities in order to cope with the ever growing waste quantities. To allocate sufficient funds for the activity, policy makers need accurate cost estimates to make an informed decision. Planners in turn need good estimation and planning techniques to provide accurate estimates. Municipality budgets are generally recurrent, consisting of costs disaggregrated into various items, such as salaries, equipment, costs of routine repair and maintenance (Schaeffer, 2000). The overall cost of the service is calculated by summing the total costs incurred in each item. Knowing the population of the area or the total waste collected in an area, the average costs per capita or per ton can be found. For example, in India, using this traditional approach the average annual costs to manage SW is estimated to be around 40USD$/ton or 3USD per capita (Zhu et al 2008, NIUA 2005). To predict future investment needs, the per ton or per capita values are multiplied with the projected quantities of wastes or population respectively for the investment period to arrive at a grand total cost. There are two problems with the current estimation method. One is that these rough estimates do not help compare costs between cities, which would help in noticing particular cities that have developed better and efficient practices. And secondly limited finances allotted to municipalities for SWM are misspent year after year as they are not allotted based on requirement but are allotted based on a recurring budget . There is no room to incorporate changing conditions or alternative systems of SWM in a city. For example, say, for a particular year, the priority is not to spend some of the allotted money on repair and maintenance of trucks but instead increase the rate of composting from 100 to 110 tons per day to handle additional quantities of waste. Such situations are common but, unfortunately, there is no system to estimate these additional costs. As a result, municipal authorities complain of lack of funds and the waste ends up getting dumped illegally. There is an urgent need to overhaul the system by making substantive changes in the financial planning and management of waste. An efficient cost planning methodology that could estimate costs of SWM could allow for easy upgrading of existing facilities. An improvement in cost planning would lead to easier cost accounting and so fewer misspent resources, leading to an improvement in service delivery (Milke 2006). More importantly, it would increase the confidence of national governments and aid agencies that an investment of resources will lead to social and environmental improvements.

Stepwise Multiple Regression, a statistical technique, is used in this paper to suggest a method for improved cost planning of SWM in IR. This is done by taking up a case study on India. The major factors influencing costs of waste management in India are also determined.

Cost estimation using Multiple Regression

Statistical techniques, such as regression analysis, are used to develop cost estimating relationships that tie the cost or price of an item (eg a product, good, service, activity) to the cost driver (one or more independent variables) (Langfield-Smith et al). It is a useful tool because it allows the estimator to develop a cost estimate quickly and easily.

Although the work done by Clark(1971), DeGeare(1971), Moon(1994), Hirsch (1965) are mainly to predict collection costs and future generation rates of SWM, it provides evidence that the procedure could be used as a simple and quick planning tool. In India the solid waste services offered by municipalities of different states do not vary greatly within the country, and neither do the factors that affect the service. For example door to door collection costs (y) which is a common service almost throughout the country, would depend on factors such as privatization (x1), collection frequency (x2), the number of housing units within the municipality jurisdiction (x3) etc. Although the magnitude of these factors may vary between cities, for example a particular city may privatize collection while the other does not, the factors influencing the collection costs are generalised. This allows for easy comparison between cities. Thus to evaluate which city performed better in terms of collection costs, by how much, and why, a regression equation relating y to x1, x2, x3,.…xn could be formulated. The coefficients of the x variables could provide useful information not only to analyze the current situation but also allow for future prediction..

Data used for analysis

The data provided in the statistical volume III of the NIUA (2005) report was used in the analysis. The NIUA study covered a sample of 305 cities and towns out of close to 700 districts in India. The sampled cities and towns in turn represent the entire country, i.e., all the 28 States and 7 Union Territories (NIUA, 2005).

Total Cost of SWM: The dependent variable and its development

The first step was to adjust the raw costs/expenditure data provided in the NIUA report to provide a consistent basis of comparison. It was intended to adjust all the data to the start of the financial year in India which is the 1st of April. The Statistical Volume III on solid waste management published by NIUA contains district-wide information on the estimated population and solid waste generation for the financial year 1999 but the expenditure on solid waste management was provided for financial year 1997-98. The expenditure on solid waste management was worked out for the financial year 1999 using rates of inflation. It is assumed that there is no change in labour costs, capital costs, land costs etc for the period of analysis. This seems justified as costs within cities within the same region for e.g. metropolitan cities for a given year will usually remain constant. Two cost studies were performed: (1) total cost per person, and (2) total cost per ton.

Per capita costs (CPC)

The method involves division of the total expenditure by the total residents. Note that the population data from the NIUA considers the population of only the "main" city; the population of the outer parts of the city has not been taken into account. Poor estimates of population, and uncollected parts of the city are potential problems that could affect the proper evaluation of per capita costs.

Per tonnage costs (CPT)

This is obtained by dividing the total cost by the total amount of waste collected or disposed in tons. This variable could be misleading because there could be parts of the city where waste is not collected, and where it is also expensive to provide services. In this case, the CPT variable would underestimate the true cost if the whole city were to be serviced.

Factors influencing total costs: The independent variables

Once the cost data from NIUA have been normalized to account for differences due to inflation, the next step is to identify the factors that influence the total cost. One can think of many factors that could possibly affect total expenditure. But only selected socio-economic variables for which data were available from the NIUA report, and those that could take discrete values that were presumed to have an effect on the dependant variable (i.e., total costs), were used in this analysis.

The following brief description of these variables indicates why/ how they were determined. All these variables are applicable for the year 1999 keeping in sync with the year for which total costs were computed.

Population Density (x1): Population density is the average number of inhabitants per square km of area under a particular municipality. This is obtained by dividing the estimated 1999 population by the estimated area (in square km) both obtained from the NIUA report.

Waste Density (x2): This is thought of as having an influence on the collection costs which in turn contributes to almost 75-80% of total costs. Waste density was measured as a ratio of waste collected per municipality in 1999 and the estimated area (in sq km) in 1999.

No. of vehicles used for transportation (x3): This was obtained by adding the total number of motorized and non-motorized vehicles used in a city/town. The fuel cost, maintenance costs for a large number of vehicles could in turn contribute to the total costs of SWM for a municipality.

Average trips per vehicle per day (x4): This is the average number of trips made by both motorized and non-motorized vehicles to transport waste to transfer stations, landfills etc. Landfills are situated far away from the expanding city decreasing the number of trips made by the transportation vehicle. The variable directly affects the working hours of transportation staff that have to be paid extra wages, the fuel rates for longer distances etc. All these have an influence on the total costs.

Total number of staff employed (x5): SWM activities are highly labour intensive in India. The salaries/wages of the staff employed contribute anywhere between 10-70% of total costs (Zhu et al). The data used here are the sum of the supervisory and sub-ordinate staff employed in the SWM sector.

Frequency of collection (x6): Collection frequency contributes to collection costs which in turn affects the total costs. Although the minimum and most frequent collection is once daily in most municipalities across the country, it varies from as often as thrice daily to just once a week. It is hence classified as a categorical variable taking the value 0 if waste is collected once daily and 1 if it is collected more than once.

Privatization (x7): Certain activities such as collection, disposal, and transportation, are privatized by contracting them to private agencies. The total cost either before or after privatization increases or decreases depending on the type of activity that was privatized as is evident from the NIUA dataset. Hence this was included as an independent categorical variable that takes the value 0 if no activity of SWM is privatized and 1 if some aspect is privatized.

Medical waste collected and disposed separately (x8): Medical wastes as per the Indian law have to be collected and disposed separately (NIUA, 2005) But as seen from the dataset, very few cities actually collect and dispose them separately perhaps fearing the additional cost that they might incur. Hence the effect of this variable on total costs was studied. This was classified as a categorical variable taking the value 0 if it is NOT collected and disposed separately and the value 1 otherwise.

Data Analysis using Stepwise Multiple Regression

A total of six analyses were performed to determine the factors influencing CPC and CPT for Metropolitan, Class I and Class II cities.

CPC= f (x1, x2, x3, x4, x5, x6, x7, x8) and

CPT = f (x1, x2, x3, x4, x5, x6, x7, x8)

Data points were typically so scattered not only in scatterplots but also in partial residual plots (i.e even after controlling for other variables), that it was hard to see if the effects were better described by something other than a strictly linear equation. Hence, initially, various transformations (such as log, square, cubed) were performed on the variables and a number of models were fitted with the transformed variables in each of the six cases to investigate any evidence for non-linearity. It was decided that only if the transformation turned out to give a statistically significant relationship at the 0.05 level would the transformation be used for further analysis. The result was that none of the transformed variables were significant. Some of them were initially significant but after careful observation of the partial residual plots, it turned out that they were strongly influenced by outliers. Hence the transformed variables were dropped and the analysis was re-run using the untransformed variables. This seemed like sufficient evidence to proceed with a linear relationship between the dependent and independent variables.

The next step was to determine which of the x variables (cost determinants) had an influence on total costs. Stepwise regression in SPSS software is used in this paper to find a model that fits the data. Stepwise methods are defensible when used in situations in which no previous research exists on which to base hypotheses for testing (Menard, 1995; Agresti and Finlay, 1986). In other words it helps when you merely wish to find a model to fit your data from a set of explanatory variables that you "think" affects the dependant variable. Since no previous study of this nature was cited in the available literature, the stepwise method was adopted for this study. Outliers seemed to have a great effect on the results in this study. But with highly scattered data such as ours, it was difficult to justify their elimination. Thus it was attempted to fit the model for the complete data. Table 1 summarises the regression equations obtained for various population ranges in India. The methodology discussed above to arrive at these regression equations has been demonstrated in the appendix using the data from metropolitan cities in India.

Table 1 : Cost estimating relationships for different population ranges in India

Population Range	**Total costs**	**Regression Equation***	**R^2**
Metropolitan	Cost per Capita	$Y_1 = -1.759 + 1159.56\, x_5 + 39623.31\, x_3$	0.626
Class I	Cost per Capita	$Y_1 = 0.918 + 435.22\, x_5 - 0.456\, x_7 + 0.062\, x_2$	0.275
Class II	Cost per Capita	$Y_1 = - 0.007 + 838.44\, x_5 + 0.178\, x_2$	0.278
Metropolitan	Cost per ton	$Y_2 = 4.58 + 858.09\, x_5$	0.200
Class I	Cost per ton	$Y_2 = 8.63 + 1.65\, x_5 – 4.57\, x_7$	0.602
Class II	Cost per ton	$Y_2 = - 1.984 + 2.29\, x_5 - 0.001\, x_1$	0.666

x1=Population Density, x2= Waste Density, x3=No. of vehicles used for transportation, x4=Average trips per vehicle per day, x5=Total number of staff employed, x6=Frequency of collection, x7=Privatization, x8= Is medical waste collected and disposed separately?
* Equation fitted through the raw data including outliers, missing values were deleted.
Data source: NIUA (2005)

Variable x_5 plays an important role in every population range. It has the same sign in all the equations indicating that it has the same effect in all cities. This highlights the observation in SW literature that the service is highly labour intensive in developing countries and that major costs are spent on establishments and salaries of staff (NIUA 2005, Zhu et al, Hanrahan et al). Thus the higher the number of staff employed the higher is total costs. At first glance, the hypothesis that other variables such x_3, x_7, x_2 and x_1 are useful in predicting total costs of SWM seems reasonable. But careful analysis of and exclusion of outliers (see appendix) showed that these other variables were either weakly significant or not significant at all when outliers were eliminated. The models suggested here must be used with caution as the equations in Table 1 are NOT a perfect fit to the scattered data. Also, there are a number of sources of uncertainty and error such as doubts about accuracy and precision of the data, outliers etc.

Although this study provides a broad insight into costs of SWM in India, further research, say by decomposing into individual activities such as costs of collection, transportation and disposal could help provide a deeper understanding. There is a need to overhaul the current budgeting system that is being followed to plan costs of SWM in industrialising regions where finances are a constraint. The method and results are presented for the Indian scenario in this paper but with the great diversity included within such a large country, it is possible that the results could be extended to other counties. It is hoped that the methodology suggested here will be a useful start, and further study on this aspect is stimulated for those working in this area particularly in developing countries.

References:

Agresti, A., Finlay, B., 1986. *Statistical methods for the social sciences*, 2nd ed. Dellen Publications, San Francisco

Clark,R.M., Grupenhoff,B.L., Garland, G.A., Klee,A.J., Oct 1971, 'Cost of residential solid waste collection', *Journal of the Sanitary Engineering Division*, v.97,p.563-68

DeGeare Jr,T.V., Ongerth,J.E., Dec 1971, 'Empirical analysis of commercial solid waste' , *Journal of the sanitary engineering division*, v.97, p.843-50

Hanrahan, D., S. Srivastava, and A.S. Ramakrishna, 2006, *Improving management of MSW in India*, World Bank (India Country Office), New Delhi.

Langfeild–Smith, K., Thorne, H., Hilton, R.W., 2003, *Management Accounting*, An Australian Perspective, McGraw Hill, Australia.

Menard, Scott.1995. Applied Logistic Regression Analysis. Sage Publications.Series: Quantitative Applications in the Social Sciences, No. 106

Milke, M.W., 2006, *The Alchemist's dream resource*, Waste Management, v. 26, p.1203-4.

Moon H., 1994, 'Solid Waste Management in Ohio'**,** *The Professional Geographer*, v. 46, Issue 2 , p.191 – 198

NIUA (National Institute of Urban Affairs), 2005, Status of Water Supply, Sanitation and Solid Waste Management in Urban Areas.

Schaeffer, M., 2000, *Municipal Budgeting*, World Bank background series.

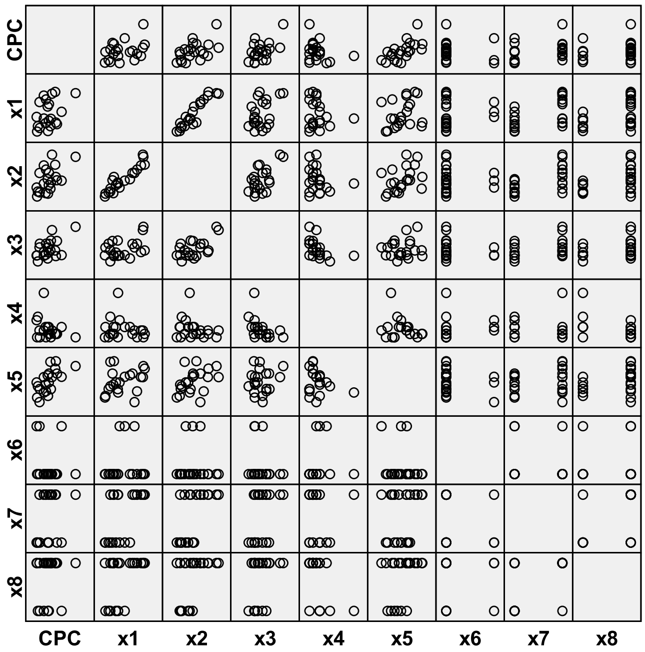
Zhu, D., Asnani, P.U., Zurbrugg , C., Anapolsky , S., Mani,S., 2008, *Improving municipal solid waste management in India*, A source book for policymakers and Practitioners, The World Bank

Appendix:

Procedure adopted to develop a regression equation using stepwise regression in SPSS 17 to develop cost estimating relationships.

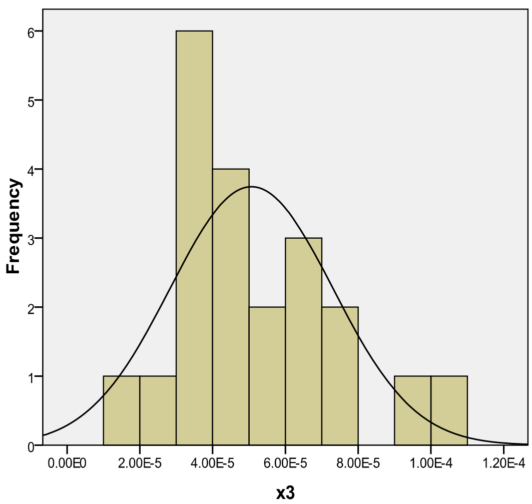
(N.B- Example shown here is for Indian Metropolitan Cities; Dependant Variable- Cost/capita (CPC or y); Independent variables- x1=Population Density, x2= Waste Density, x3=No. of vehicles used for transportation, x4=Average trips per vehicle per day, x5=Total number of staff employed, x6=Frequency of collection, x7=Privatization, x8= Is medical waste collected and disposed separately?)

Step 1: Observe scatterplot matrix of variables to check for patterns/trends of variables.

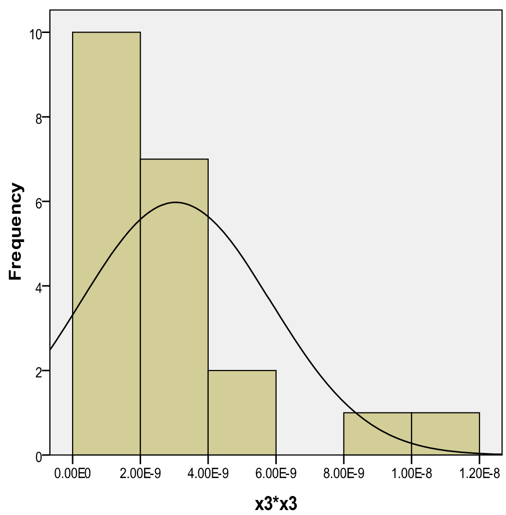


Result: Highly scattered data. No obvious trend observed between variables.

Step 2: Check for non-linearity by applying transformations to each variables and checking if they are significant at 0.05 level (Example shown here is for x3 only using squared transformation. Other transformations such as log, square root also tried)



Raw data



Square Transformed

Result: No transformation necessary as untransformed variables are significant and also normally distributed.

Step 3: Stepwise regression Model Coefficients with and without outliers
(outliers analysed in Step 4)

	Unstandardized Coefficients		Standardized Coefficients	
	B	Std. Error	Beta	Sig.
Model 1: All Raw data included*				
(Constant)	-1.759	.851		.053
x5=Total no. of staff employed/capita	1159.561	290.070	.582	.001
x3= No.of vehicles used for transportation/ capita	39623.311	12530.555	.460	.005
Model 2: Without outliers**				
(Constant)	.403	.621		.525
x5=Total no. of staff employed/capita	977.566	283.334	.631	.003

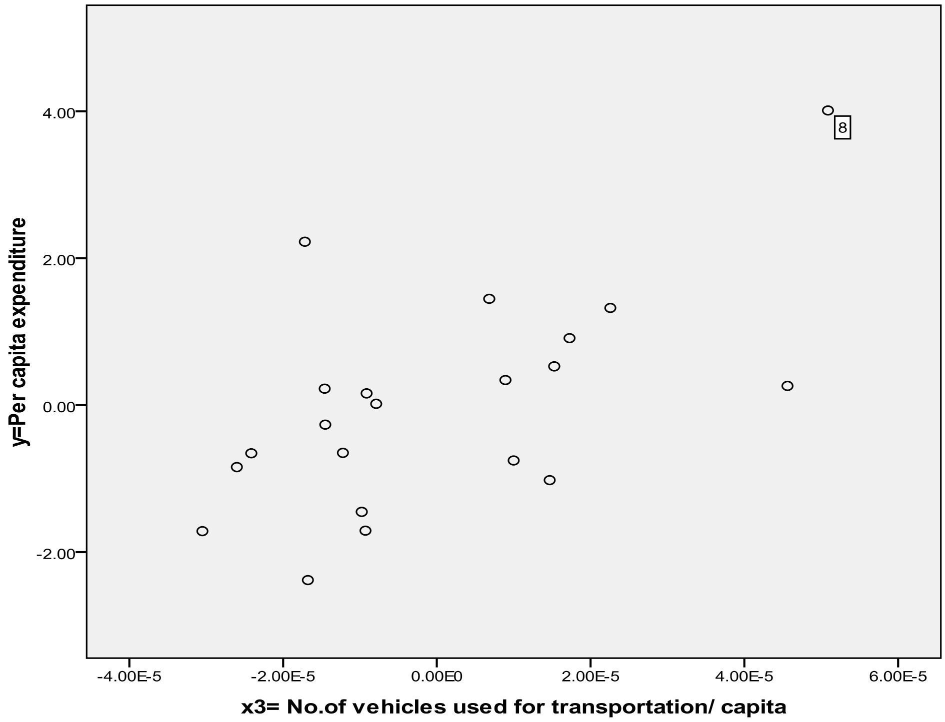
*R Square=.626, Standard Error of Estimate= 1.241

** R Square=.398, Std. Error of Estimate= 1.16

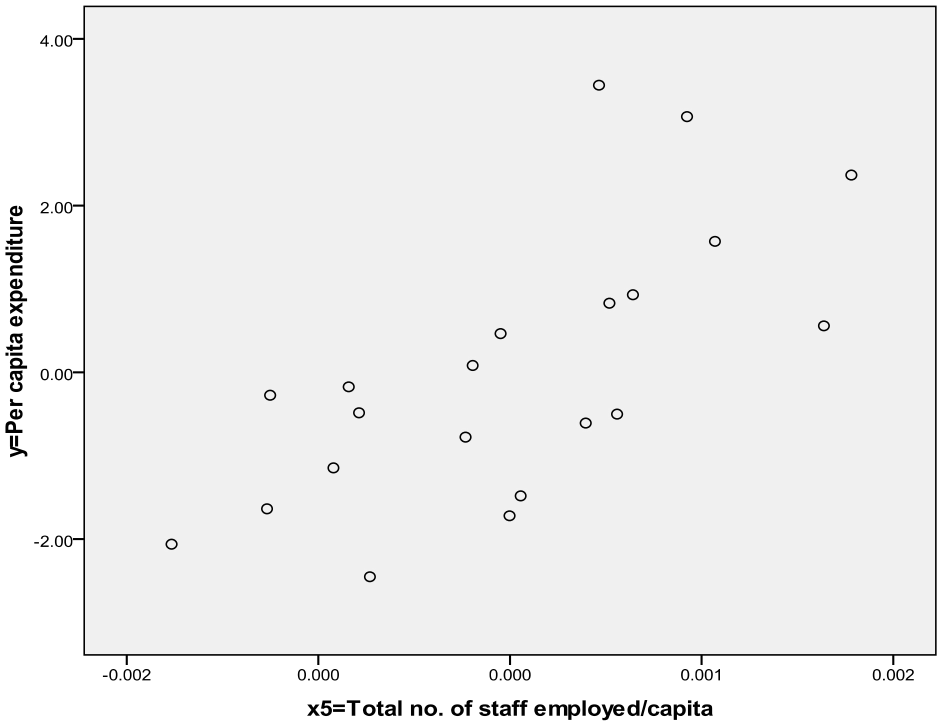
Result: Model with outliers (two significant variables) Y_1= -1.76 + 1159.56x_5 + 39623.31 x_3

Model without outlier (1 significant variable) Y_1= 0.403 + 977.57 x_5

Step 4: Analyse outliers (if present) and their effect on linear regression results



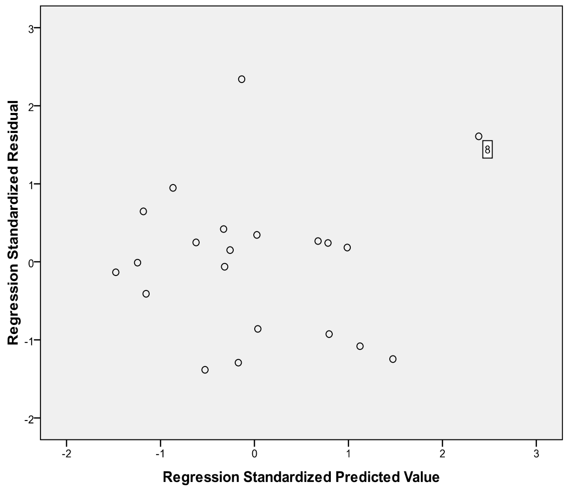
(a)Effect of variable x3 after controlling x5



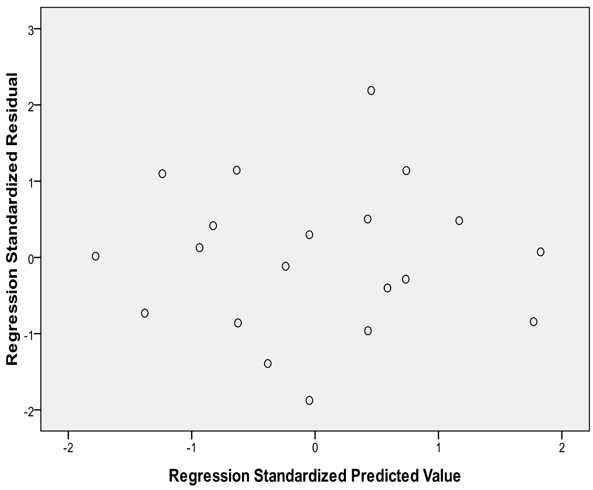
(b) Effect of variable x5 after controlling x3

Result: Note presence of an outlier affecting the linear trend in (a) whereas a clear linear trend between x_5 and y and in (b)

Step 5: Check residual plots to ensure assumption of constant variance is satisfied



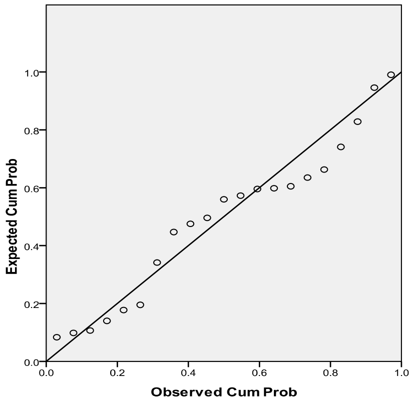
(c) with outlier



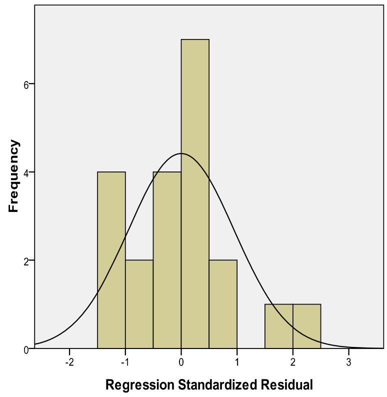
(d) without outlier

Result: (c) shows assumption is violated due to outlier but when outlier is removed in (d) residuals is randomly distributed indicating constant variance.

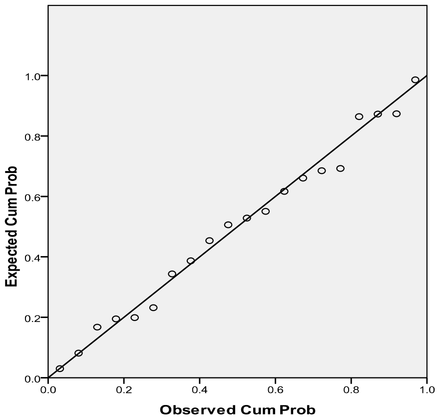
Step 6: Check Normality Plots for residuals



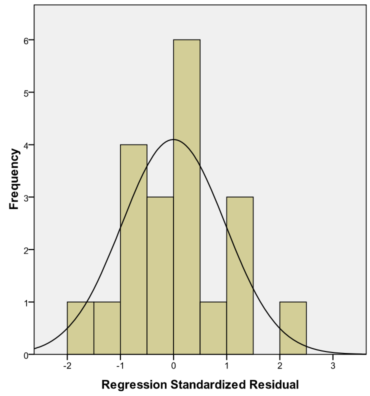
(e) Normal pp plot with outlier



(f)Histogram of residuals with outlier



(g)Normal pp plot without outlier



(h)Histogram of residuals without outlier

Result: (g) and (h) indicate residuals are more normally distributed compared to (e) and (f)