

# Electronic versus Paper-based data collection for conducting health-care research: A cost-minimization analysis

Sirshendu Chaudhuri (✉ [sirshendusisu@gmail.com](mailto:sirshendusisu@gmail.com))

ICMR-National Institute of Epidemiology

**Bhavani Shankara Bagepally**

ICMR-National Institute of Epidemiology <https://orcid.org/0000-0003-0856-767X>

**Ditipriya Bhar**

ICMR-National Institute of Epidemiology

**S. Uday Kumar**

Apollo Institute of Medical College and Research, Chittoor

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## Research Article

**Keywords:** Cost comparison, Cost-estimation, Cost-minimization Analysis, Data collection, Paper-based data collection (PDC)

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### Authors details:

Sequenc e	Authors' name and Affiliation	Email ID	Specific Contribution
1	Sirshendu Chaudhuri, ICMR- National Institute of Epidemiology, Chennai, India	<a href="mailto:sirshendusisu@gmail.com">sirshendusisu@gmail.com</a>	Study conception and design, Acquisition of data, Analysis and interpretation of data, Drafting of manuscript
2	Bhavani Shankara Bagepally, ICMR- National Institute of Epidemiology, Chennai, India	<a href="mailto:bshankara@gmail.com">bshankara@gmail.com</a>	Acquisition of data, Analysis and interpretation of data, Drafting of manuscript, Critical revision

3	Ditipriya Bhar, ICMR- National Institute of Epidemiology, Chennai, India	<a href="mailto:ditipriya.bhar@gmail.com">ditipriya.bhar@gmail.com</a>	Analysis and interpretation of data, Critical revision
4	S. Uday Kumar Reddy, Apollo Institute of Medical College and Research, Chittoor, India	<a href="mailto:11ludaykumarreddy222@gmail.com">11ludaykumarreddy222@gmail.com</a>	Acquisition of data, Critical revision

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**Corresponding Author:**

Dr. Sirshendu Chaudhuri,

Consultant I (Online courses Division),

ICMR-National Institute of Epidemiology, Chennai.

Contact- 8778183569

E-main ID: [sirshendu@nieicmr.org.in](mailto:sirshendu@nieicmr.org.in) / [sirshendusisu@gmail.com](mailto:sirshendusisu@gmail.com)

**Title: Electronic versus Paper-based data collection for conducting health-care research:  
A cost-minimization analysis**

**Abstract:**

**Introduction-** Containing expenditure and efficient resource use is essential to limit the increasing costs of health research. Electronic data collection (EDC) is thought to reduce the costs compared to paper-based data collection (PDC). Economic evidence in this area is scanty,

especially in low and middle-income countries. Hence, an economic evaluation was conducted to compare the cost between EDC and PDC

**Methods-** A cost-minimization study was conducted to compare between EDC and PDC from the institutional perspective for the year 2018, based on a community-based survey. Step-down cost accounting was adopted with a bottom-up approach for cost estimation. Total and unit costs were estimated with the base case comparison between EDC and PDC while using SPSS software (e-SPSS and p-SPSS, respectively). We conducted scenario analyses based on usage of different software, R and STATA for both EDC and PDC (e-R, p-R, e-STATA and p-STATA respectively). One-way and probabilistic sensitivity analysis (PSA) was performed to examine the robustness of the observed results.

**Results-** In the base-case analysis, total costs of EDC and PDC were ₹72,617 (\$1060.9) and 87,717 (\$1281.5) respectively- with estimated cost minimization of ₹ 15,100 (\$220.6). In other scenarios, the estimated cost minimization for e-R, e-STATA, p-R, p-STATA were ₹ -274 (\$4.0), 98 (\$1.4), 14826 (\$216.6), and 15,002 (\$219.2) respectively when compared to EDC-SPSS. On one-way and PSA, the results of the cost-minimization analysis were robust.

#### **Conclusion-**

The EDC minimizes institutional cost for conducting health research. This finding will help researchers in planning for the budget for their research to use the resources efficiently

#### **Keywords:**

Cost comparison, Cost-estimation, Cost-minimization Analysis, Data collection, Paper-based data collection (PDC)

## **Introduction**

A sustainable health research environment requires an integrated contribution from individual, institutional, national and international solidarity. A major proportion of health research costs in low-and middle-income countries (LMICs) are contributed by the donor funding and grants. (1) However, available funding resources are much limited in comparison of what is required. (2) Therefore, the cost of research can be well managed by systematic planning and implementation as well as efficient use of resources during data collection, management and analysis. (2)

Paper-based data collection (PDC) using paper case report forms (CRFs) are the conventional method of data collection in health research. Additionally, PDC can be a laborious and error-

prone process. (3) With the innovation of information technology, an increasing trend of use of electronic data collection (EDC) has been observed in many regions of the World. (4) Evidence suggests that in LMIC settings, EDC may serve as an effective platform to collect and transfer large quantities of data successfully. (5) In India, although systematic evidence on the use of EDC is lacking, the Indian government's policy on the use of m-health for service delivery by health workers is an indication of an increasing trend in the application of EDC. (6) With the advent of Health Information Technology in India, there is an increasing trend of EDC by small to extensive scale surveys and trials than traditional PDC in researches. (7–9) Current literature from different country settings has identified various advantages of EDC when compared to PDC. It is reported that EDC ensures increased accuracy, greater efficiency of data capture, better quality control of data management, rapid analysis of data, as well as a reduction in the cost of data collection. (3,4,10–12) However, the cost of EDC and PDC can be contextually different and study-specific. (4) Despite the rapid increase of EDC in India, there is hardly any study examining the cost difference between the two methods. Hence, based on a cross-sectional survey, an economic evaluation from the institute's perspective was conducted to examine the cost difference between the costs of traditional PDC and EDC.

## **Methods**

An economic evaluation was conducted by a cost-minimization analysis approach to examine the costs incurred in different modes of data collection and methods applied while conducting health research. This economic evaluation is based on a single community-based survey (13) in the state of Andhra Pradesh, India. This survey was conducted in a rural area of Andhra Pradesh from a private medical college. The survey was conducted from May to September 2018. Data for this study was collected electronically through an android device using KoBoCollect open data kit (14)

Retrospectively costing was assigned to this survey. (13) For costing, a step-down cost accounting was adopted with a bottom-up approach. All the costs were estimated from an institutional perspective. We identified different cost centres and cost components within each of the cost centres for various activities/processes involved in the study. Then we imparted costs for each of the components. All the costs were estimated in Indian Rupee (₹) for the year 2018 (Also converted into USD; conversion rate: 1\$= 68.45₹ as on 1st July 2018). As the study was of a short period (less than one year), we have not discounted costs.

Cost minimization is the primary outcome of this study. Data collection for the original survey was done electronically, and analysis was done using the Statistical Package for Social

Sciences Software (SPSS). Similarly, we have imparted costs for all the relevant cost components for PDC, with a fixed study sample size, the same as that of EDC. Thus, we estimated costs of the survey (p-SPSS) assuming that PDC would have been done instead of EDC in relevant cost centres. Then the cost minimization was estimated as the difference in total costs between EDC and PDC mode of data collection.

Then for different scenarios of conducting the same study using different data analysis software was considered. For scenarios, we estimated the costs of the survey if other software like 'R' and 'STATA' would have been used for data analysis for both EDC and PDC approaches. These costs were termed as e-R and e-STATA when EDC was done, and data analysis software were R and STATA, respectively. Similarly, p-R and p-STATA, when PDC was done with analysis using R and STATA, respectively. To examine the uncertainty of results, a one-way sensitivity analysis was conducted by lowering or increasing the individual cost components by 25%. Also, probabilistic sensitivity analysis (PSA) was conducted by simulating the various components of the cost data using a gamma distribution. Based on the assumption that, if the same survey was conducted in low, medium, and high-cost settings, all the respective cost components were documented (supplementary table- 1). For example, the cost of a medical college can be situated in a rural setting (Low-cost setting), small towns and cities (medium cost setting) or in metropolitan cities (High-cost setting) where the costs of same items can vary. Using these estimates from three different settings, the measures of dispersion were calculated and used as input while conducting the PSA. All the analyses were performed in Microsoft Excel 2019.

**Ethical compliance-** The institutional ethics committee clearance has been obtained to conduct the study.

## **Results**

The primary study (13) was conducted with a sample size of 102 subjects. The steps of the survey were broadly divided into three phases- preparation, data collection, and data analysis and storage (Figure 1).

All identified cost centres and its component costs for both EDC and PDC mode of data collection were tabulated in Table 1. The costs of the preparatory phase and the data collection phase were similar for both EDC and PDC, with minimal variation between the two. A significant difference in costs between EDC and PDC was noticed in the costs related to data entry and CRF storage section. (Table 1)

The estimated total costs of EDC-SPSS and PDC-SPSS were ₹ 72,617 and ₹ 87,717 respectively- with estimated cost minimization of ₹ -15,100 (Table 2). The data analysis and storage section of cost centres contributed ₹ 14,154 (93.7%) of total cost minimization. In scenario's analysis, estimated cost minimization for EDC-R, EDC-STATA, PDC-R, PDC-STATA were ₹-274, ₹-98, ₹14826 and ₹15,002 respectively when compared to EDC-SPSS. In the one-way sensitivity analysis, the cost minimization between EDC-SPSS and PDC-SPSS was robust with maximum variation was only <8 % even with a 25% change in the individual component costs. The most sensitive cost inputs were transportation-related vehicular costs for data collection, the salary of the researcher and the costs of data analysis. (Figure 2). The one-way sensitivity analysis results of all the scenarios were robust with minimal deviation from that of observed base case results (Supplementary Figures S1-S3).

In PSA (Figure 3), results were robust as the PSA mean cost minimization between e-SPSS as compared to p-SPSS were similar to that of base case values (Table 2). Similarly, even in the PSA results in different scenarios were also robust and similar to that cost minimization from the respective base case analysis. Since the costs of software (R and STATA) could not be varied; hence we could not calculate the measures of dispersion and hence both PSA and base-case values were the same. Results of PSA of cost-minimization analysis were shown in a scatter plot with X-axis indicating the total costs of the comparator (p-SPSS) while the Y-axis was indicating the comparators (e-SPSS, e-R, e-STATA, p-R, p-STATA). (Figure 3)

## **Discussion-**

In this economic evaluation, we have examined the cost minimization that could result from the use of EDC using open-source electronic questionnaires when compared with traditional PDC. We observed that the use of EDC reduces the total cost of health-research by 17%. Higher costs of PDC were mostly (93.7%) contributed by the cost of data entry and CRF storage. This finding holds good for commonly used software for data analysis.

Estimating the cost-minimization due to EDC is complex and study-specific. One study from South Africa (4) estimated that EDC could reduce the study cost by 50% over the traditional PDC. Contemporary evidence from other parts of the World also indicates similar findings that the cost minimization can vary between 49% to 62%. (15) This minimization could be at various levels of the study. In the present study, we found more than 90% of the estimated cost

minimization was out of double data entry and the storage of paper case record forms (CRFs). The process involved with tedious data entry, and the necessary data cleaning, reduces the duration of health research and resulting costs involved in it. (16–18) Evidence from LMICs like Ethiopia and Tanzania have shown that the use of EDC reduced the costs by 25%. (3,19) However, the economic evaluation from Ethiopian study (19) considered the cost of electronic devices as single-use, which may cause an over-estimation of cost for EDC.

Although, the cost of the data collection device didn't influence the cost minimization, the choice of device may affect cost minimization. (20) The types of electronic devices may affect the accuracy of the data collection as well in the field due to variation in size, and specification (16). The estimated cost minimization can be affected by the initial expenditure associated with the establishment of a system in an Institution for using EDC methods instead of PDC. (11,21) For example, we used an open-source tool for developing electronic questionnaires in our study. Use of a paid version of a similar tool could have altered the estimate.

The present study highlights various costs incurred to conduct the study from the institutional point of view at various stages of short-duration, community-based survey. Such findings will help in planning for the necessary set-up required by an institution to adopt the EDC approach instead of PDC in health research. The initial planning includes- motivating and training the researchers, technologies needed, financing, maintaining the technology, and solving the ethical concerns associated with handling the data. (10,22,23) Once an electronic data capture system is established in an institution, it can save additional resources like costs, and the researchers can focus better on their research activities. (24)

### **Limitation-**

In the present study, we could not account for the costs in a few aspects of health research. These include- the cost associated with data cleaning in case of PDC, maintenance charge during storage of data collection. We could not impart such charges as the original study sample size is relatively small and thus finding the present study should be examined cautiously for larger studies. As we use an open-source tool for data collection, the actual cost may vary if an institution could use a paid tool for EDC. The study explored the costs of public health research. Further study observations may not be extended for clinical trials.

### **Conclusion and recommendation-**

We observed cost-minimization with the use EDC approach as compared to the PDC approach while conducting health research cross-sectional single Centre study. For short studies, we

strongly recommend using EDC. We also recommend that the research institutions should priorly assess the potential cost of preparation and maintenance related to technologies associated with EDC by incorporating all the stakeholders. Further cost-minimization analysis is warranted for clinical trials and multicentric studies in this area to have a better policy decision by all stakeholders.

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**Table 1: Cost centres and its component costs for electronic and paper-based data collection**

Cost centers	Sources of costs	Electronic CRF			Pape CRF		
		Unit cost	No. of units	Total costs	Unit cost	No. of units	Total costs
<b>A. Preparation</b>							
Stationary	Institution	30.0	1	30.0	30.0	1	30.0
Computer	Institution	45.7	14	639.8	45.7	14	639.8
Internet connection	Institution	4.4	12	52.8	4.4	12	52.8
Institutional space used	Based on average local rent	66.7	12	800.4	66.7	12	800.4
Electricity charges	Institution	10.4	9.6	99.8	10.4	9.6	99.8
Translation	Local market rate	250.0	1	250.0	250.0	1	250.0
Salary of first researcher/ hour	Institution	375.0	48	18000	375.0	48	18000.0
Salary of second researcher/ hour	As per ICMR salary for JRF	129.2	24	3100.8	129.2	24	3100.8
Salary of social worker/ day	Institution	400.0	5	2000.0	400.0	5	2000.0
Transport (Car)	Institution	10.0	200	2000.0	10.0	200	2000.0
Android device for piloting/ day	Market rate for 2018	13.7	4	54.8			
<b>B. Data collection</b>							
Printing questionnaire	Institution	-	-	-	4.5	110	495.0
Stationary	Institution				500.0	1	500.0
Printing information sheet and consent form	Institution	7.5	110	825.0	7.5	110	825.0

Salary of second Researcher/ hour (for data collection)	As per ICMR salary for Junior Research Fellow	129.2	192	24806.4	129.2	110	14212.0
Transport charge (Bike)	Institution	3.0	1080	3240.0	3.0	1080	3240.0
Instrument 1- Weighing scale	Institution	0.9	24	21.6	0.9	24	21.6
Instrument 2- Height measuring scale	Institution	1.6	24	38.4	1.6	24	38.4
Instrument 3- Measuring cups	Institution	25.0	1	25.0	25.0	1	25.0
Android device for electronic data collection	Market rate for 2018	13.4	24	321.6	-	-	-
Internet connection	Institution	4.4	24	105.6	-	-	-

### C. Data analysis and storage

Data entry person (First)/ day	ICMR salary for data entry operator	-	-	-	533.3	4	2133.2
Data entry person (Second)*	ICMR salary for data entry operator	-	-	-	533.3	4	2133.2
Institutional space used (For data entry)	Based on average local rent	-	-	-	66.7	8	533.6
Electricity charges (During data entry)	Institution	-	-	-	10.4	7.3	75.9
Data storage in cloud (KoBotoolbox)	KoBoToolbox#	0	1	0	-	-	0
CRF storage (For a period of 5 years) †	Institution	-	-	0	8612.5	1	8612.5
Files to keep printed CRF	Institution	-	-	0	100.0	3	300.0
Computer used for data entry	Institution	-	-	0	45.7	8	365.6

SPSS cost	Institution	27.4	10	274.0	27.4	10	274.0
Computer used for data analysis	Institution	45.7	10	457.0	45.7	10	457.0
Institutional space used (For data analysis)		66.7	10	667.0	66.7	10	667.0
Electricity charges for data analysis	Institution	10.4	12.5	130.0	10.4	12.5	130.0
Salary of first researcher for data analysis	Institution	375.0	40	15000.0	375.0	40	15000.0

\*Assuming double data entry

† Including cost of cupboard, and maintenance

ICMR-Indian Council of Medical Research, JRF-Junior Research Fellow

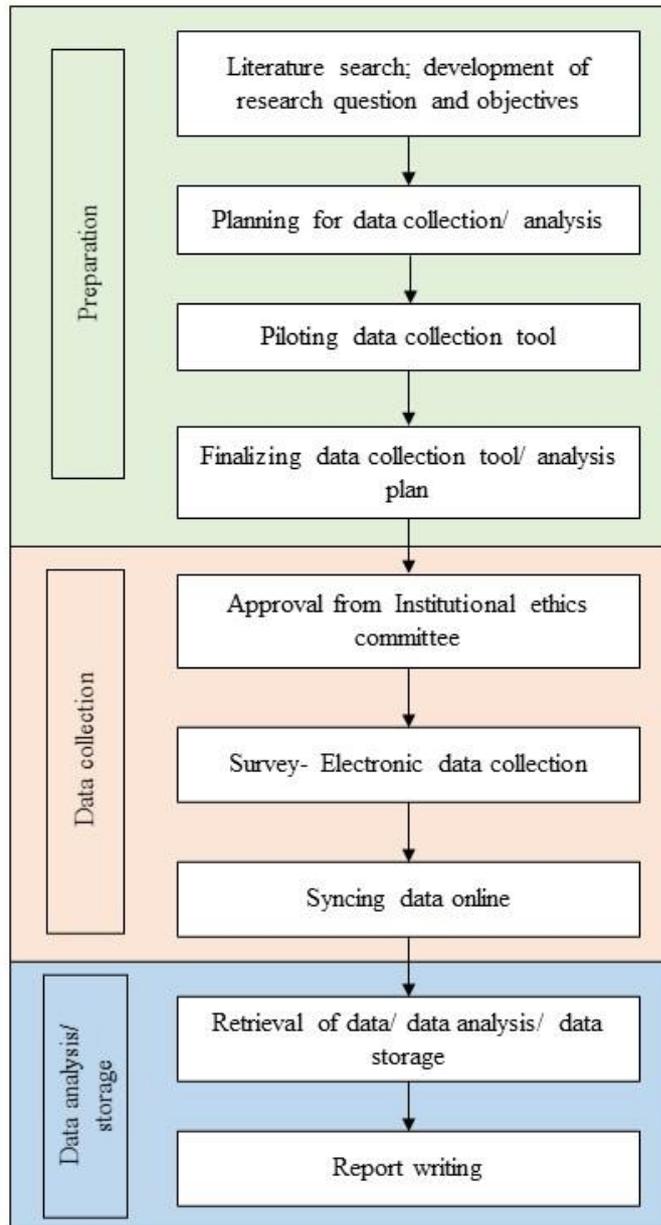
**Table 2: Total cost of various modes of data collection**

Type of CRF	Total cost in ₹ (\$)	Cost minimization in ₹ (\$)	PSA cost minimization	
			in ₹	In \$
p-SPSS	87717 (1281.5)	-	-	
e-SPSS	72617 (1060.9)	15100 (220.6)	15895 (14910, 17132)	232.2 (217.8, 250.3)
<b>Scenario Analysis</b>				
p-R	87443 (1277.5)	-274 (4.0)	-274*	-4
e-R	72343 (1056.9)	15374 (224.6)	15895 (14910, 17132)	232.2 (217.8, 250.3)
p-STATA	87619 (1280.0)	98 (1.4)	98*	1.4
e-STATA	72519 (1059.4)	15198 (222.0)	15993 (15008, 17230)	233.6 (219.3, 251.7)

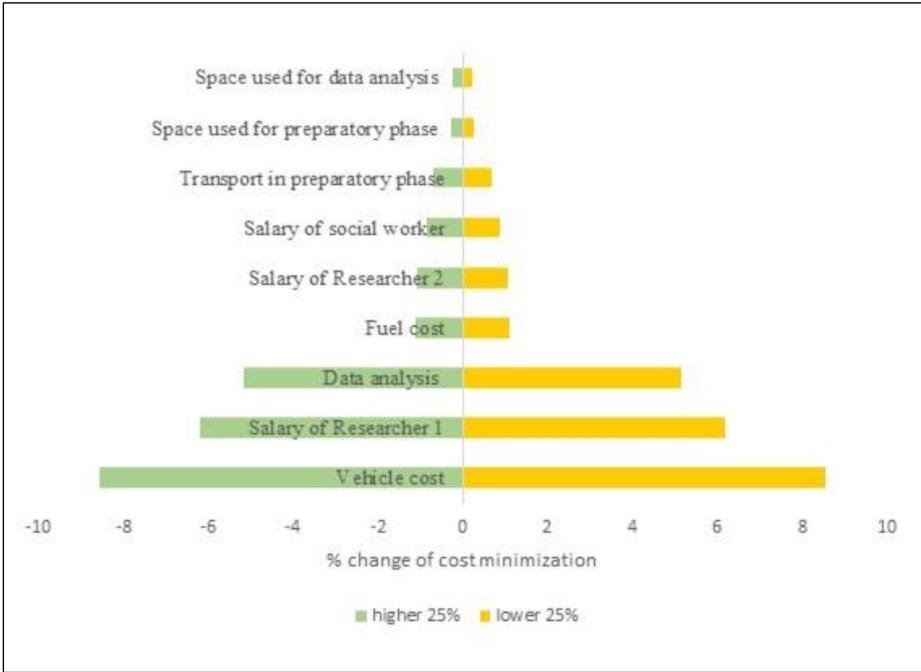
(all costs in ₹ for the year 2018)

\*Fixed in PSA

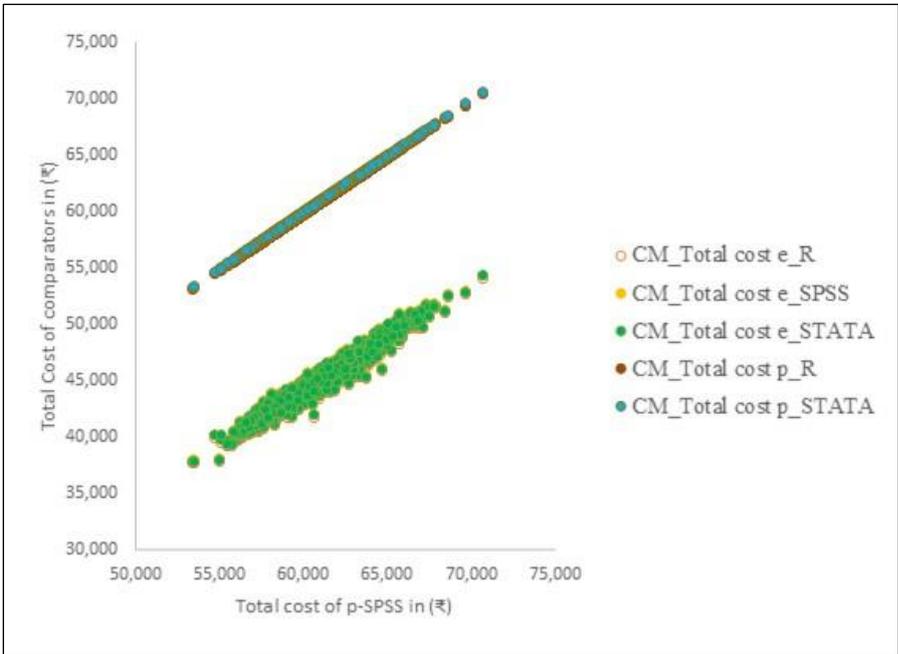
**Figure 1: Steps of the primary survey**



**Figure 2: One-way sensitivity analysis for comparison between e-SPSS and p-SPSS**



**Figure 3: Scatter plot of results PSA between total cost of different mode of data collection with PDC-SPSS**



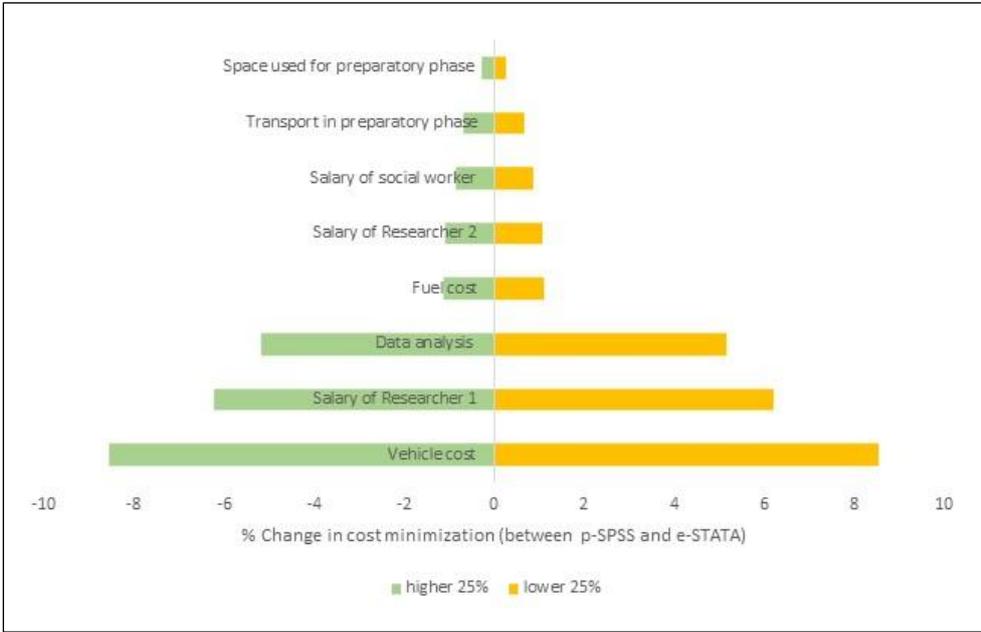
**Supplementary table 1: Cost assumption in different setting for probabilistic sensitivity analysis**

Cost centers	Unit cost (₹) in different setting				Mean total cost (SD) [Avg. unit cost* No. of units]
	Actual cost incurred	Low-cost setting	Medium cost setting	High cost setting	
<b>A. Preparation</b>					
Stationary	30	20	40	60	37.5 (17.1)
Computer	45.7	27.4	38.2	57.2	589.8 (175.7)
Internet connection	4.4	4.4	4.4	4.4	52.8
Institutional space used	66.7	58.3	97.2	116.7	1016.7 (324.7)
Electricity charges	10.4	10.4	10.4	10.4	99.84
Translation	250	200	300	400	287.5 (85.4)
Salary of first researcher/ hour	375	291.6625	333.3375	416.6625	17000.0 (2582.0)
Salary of second researcher/ hour	129.2	129.2	129.2	129.2	3100.8
Salary of social worker/ day	400	433.3	467.7	500	2251.3 (215.9)
Transport (Car)	10	8	11	12	2050.0 (341.6)
Android device for piloting/ day	13.7	11	16.4	20.5	61.6 (16.2)
<b>B. Data collection</b>					
Printing questionnaire	4.5	3	6	9	618.8 (281.8)
Stationary	500	500	500	500	500
Printing information sheet and consent form	7.5	5	10	15	1031.3 (469.7)
Salary of second researcher/ hour (for data collection)	129.2	129.2	129.2	129.2	24806
Transport charge (Bike)	3	2.5	4	5	3915.0 (1200.7)
Instrument 1- Weighing scale	0.9	0.7	1.1	1.2	23.4 (5.3)
Instrument 2- Height measuring scale	1.6	0.9	1.8	2.3	39.6 (13.9)

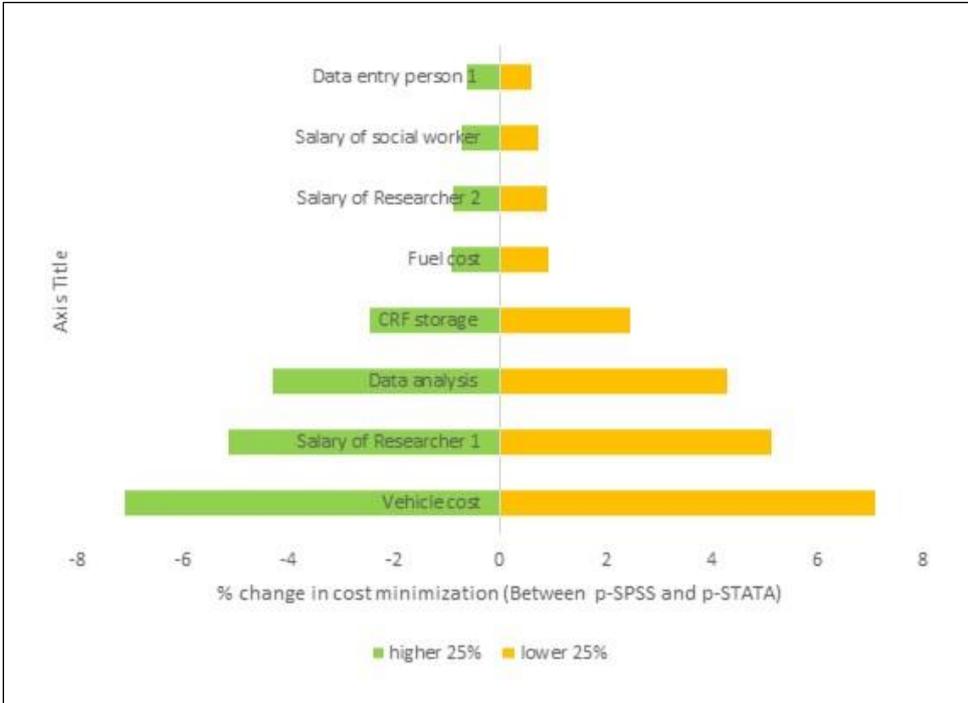
Instrument 3- Measuring cups	25	25	25	25	25
Android device for electronic data collection	13.7	11	16.4	20.5	369.6 (97.3)
Internet connection	4.4	4.4	4.4	4.4	105.6
<b>C. Data analysis and storage</b>					
Data entry person (First)/ day	533.3	533.3	533.3	533.3	2133.2
Data entry person (Second)*	533.3	533.3	533.3	533.3	2133.2
Institutional space used (For data entry)	66.7	50	83.3	100	600 (172.1)
Electricity charges (During data entry)	10.4	10.4	10.4	10.4	75.92
Data storage in cloud (KoBotoolbox)	0	0	0	0	0
CRF storage (For a period of 5 years)**	8612.5	8612.5	8612.5	8612.5	8612.5
Files to keep printed CRF	100	80	125	150	341.3 (91.1)
Computer used for data entry	45.7	27.4	38.2	57.2	337.0 (100.4)
SPSS cost	27.4	27.4	27.4	27.4	274
Computer used for data analysis	45.7	27.4	38.2	57.2	421.3 (125.5)
Institutional space used (For data analysis)	66.7	50	83.3	100	750.0 (215.1)
Electricity charges for data analysis	10.4	10.4	10.4	10.4	130.3
Salary of first researcher for data analysis	375	291.6625	333.3375	416.6625	14166.6 (2151.6)

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**Supplementary Figure S-1: One-way sensitivity analysis for comparison between p-SPSS and e-STATA**



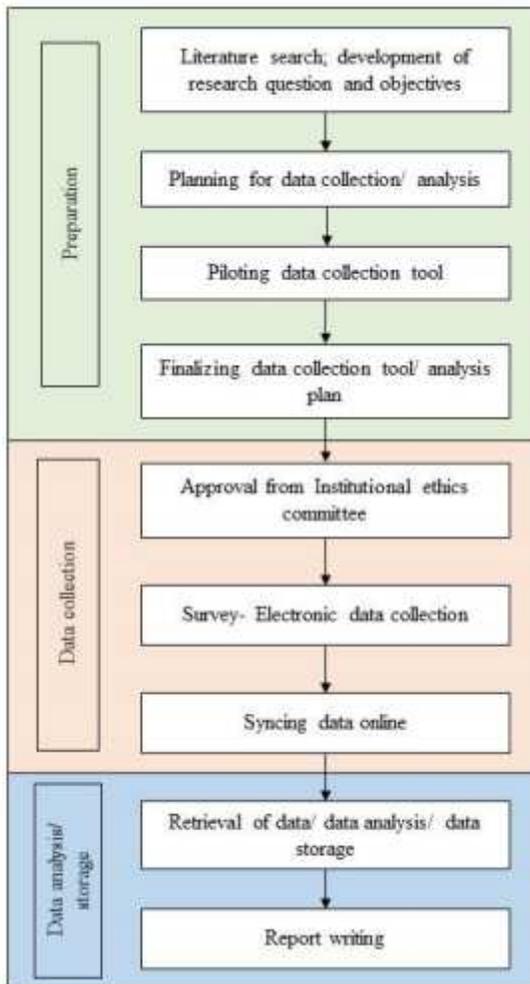
**Supplementary Figure S-2: One-way sensitivity analysis for comparison between p-SPSS and p-STATA**



**Supplementary Figure S-3: One-way sensitivity analysis for comparison between p-SPSS and p-R**



# Figures



**Figure 1**

Steps of the primary survey

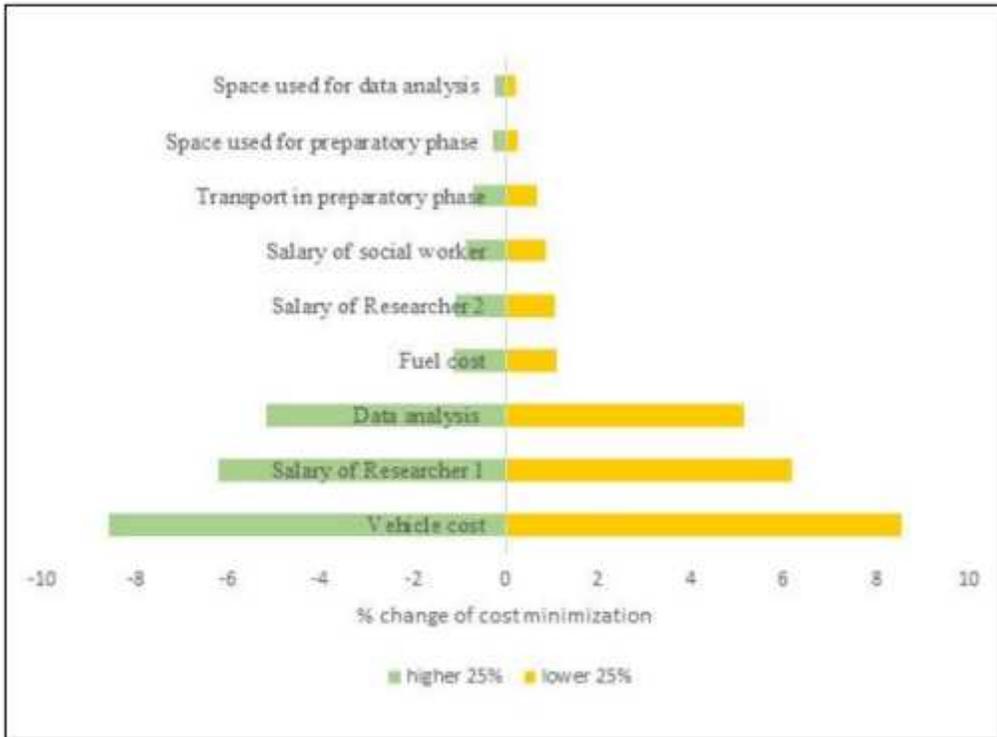


Figure 2

One-way sensitivity analysis for comparison between e-SPSS and p-SPSS

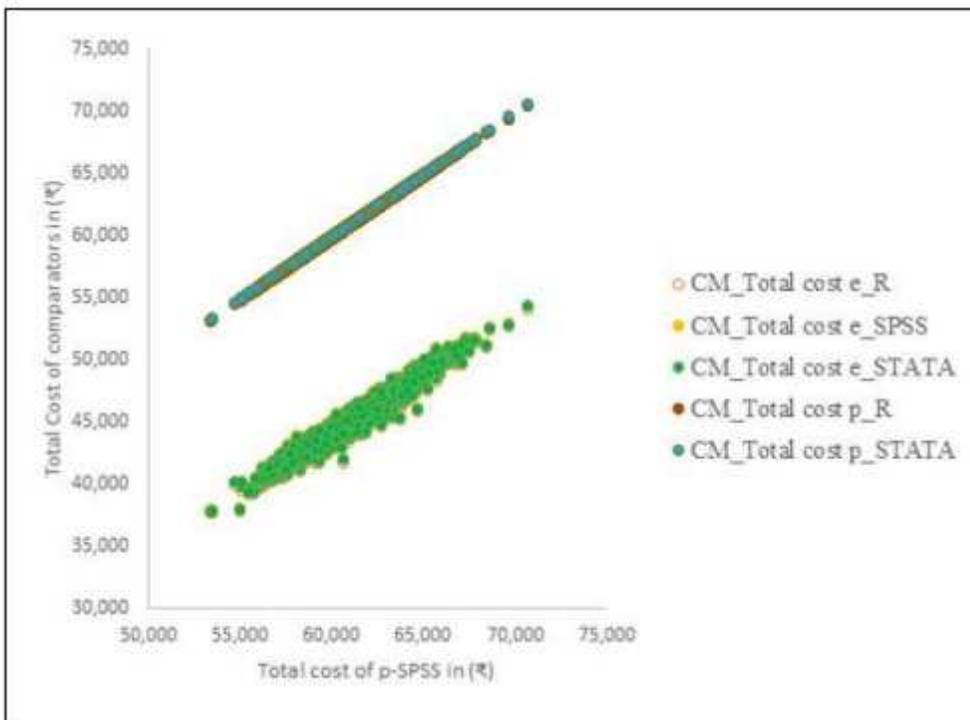


Figure 3

Scatter plot of results PSA between total cost of different mode of data collection with PDC-SPSS