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An empirical investigation into salient aspects of Delhi Metro

KEYWORDS: Delhi Metro, Passengers, convenience

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ABSTRACT *The importance and contribution of Delhi metro is known to each one of us. It has added a new way of living, connecting and thus has reduced the travel time, added to comfort, affordability and manifold benefits. The present paper attempts to understand the selected aspects of Delhi Metro and its outcome on passengers. The study attempts to assess the outcome and value that varied aspects of Delhi Metro adds to the individual life and thus realizing its importance to improvise the services further.*

Introduction
Delhi has the dubious distinction of having highest no. of vehicles among the four metropolitan cities of India. (Delhi, Mumbai, Kolkata, Chennai). Delhites consider their cars as their status symbols-- the bigger the better. This obsession for personal vehicles has put Delhi in a situation that the total no. of personalized vehicles in Delhi is more than the combined total of other three metros put together.

Need of study
Delhi has the dubious distinction of having highest no. of vehicles among the four metropolitan cities of India. (Delhi, Mumbai, Kolkata, Chennai). Delhites consider their cars as their status symbols-- the bigger the better. This obsession for personal vehicles has put Delhi in a situation that the total no. of personalized vehicles in Delhi is more than the combined total of other three metros put together.

As shown in the table below, the total no. of vehicles in Delhi has increased fourfold during the period 1985 to 2001. It can also be noticed here that the rate of growth of personalized vehicles is more than other types of vehicles. The average annual growth rate works out to be close to 20%. At this rate, about 500 new vehicles are added on the Delhi roads every day.

There are three main sources of air pollution in Delhi: Industries, Thermal Power Plants & Vehicles, out of these, vehicles contribute maximum to the overall air pollution as per the data collected by CRRI, New Delhi.

Another point to be noticed here is that almost 90% of these vehicles are privately owned. Therefore, there is a vast potential for an efficient public transport system to reduce pollution due to these private vehicles. But unfortunately, the public transport system in existence before the advent of the metro was both inefficient and insufficient.

Hence it is expected that Delhi Metro will emerge as an efficient alternative Mass Rapid Transport System (MRTS). It will motivate these private vehicle owners to shift to Metro. This in turn will lead to a significant reduction in air pollution in Delhi.

Objectives of study
The researcher concentrated himself mainly on the five major aspects of this study, mainly:-

- Reduction in numbers of vehicles on the roads.
- Decrease in air pollution level in the areas around Metro corridors.
- Saving in travel time
- Comfort in travelling by Metro
- Safety in travelling by Metro

Review of Literature
Analysis and Interpretation
Thus based on the above review of study the following Hypothesis were set-

Thus appropriate key Hypotheses were developed on above parameters as under:-

Hypothesis No. 1 (H1)
H1. Has there been any reduction in the number of vehicles on the road on account of introduction of Metro network?

Hypothesis No. 2 (H2)
H2. Has there been a decrease in the air pollution level in the area around Metro Corridor used by a passenger?

Hypothesis No. 3(H3)
H3. Has there been a saving in travel time by the introduction of Metro network in various areas

Hypothesis No.4 (H4)
H4. Has Metro been found to be a comfortable mode of travelling as compared to other modes of travelling?

Hypothesis No.5(H5)
H5. Whether Metro travel is a safer mode of travel as composed to the earlier modes of travel used by pas-

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sengers?

Correspondingly, Null Hypotheses (H0) and alternative hypotheses (Ha) were also formulated as under:-

For Hypothesis No.1
Null Hypotheses (H_O)
For the above data, let us assume that; There is no significant reduction in the number of vehicles on the road after the introduction of Metro network. This will be looked upon as Null – Hypothesis (H_0).

Alternative Hypothesis (Ha)
Therefore, H_a (alternative hypothesis) will be that there is a significant reduction in the number of vehicles on the road on account of introduction of the Metro.

For Hypothesis No.2
Null Hypotheses (H_O)
Let us assume that; There no significant reduction in the pollution levels on account of introduction of Metro. This will be looked upon as H_0 (Null Hypothesis).

Alternative Hypothesis (Ha)
Thus, H_a (alternative hypothesis) will be thatthere is a significant reduction in the pollution levels an account of introduction of Metro.

For Hypothesis No.3
Null Hypothesis ; H0
From the above data, let us assume that;

There is no significant saving in travel time of the passengers now availing themselves of the Metro facility.

Alternative Hypothesis Ha
Therefore, H_a (Alternative Hypothesis) will be that there is a significant saving in travel time of the passengers now availing themselves of this Metro facility.

For Hypothesis No.4
Null Hypothesis H0
Let us assume that the Null Hypothesis (H_0) is that;

Introduction of Metro has not been significant enough to be comfortable to the passengers as a mode of transportation.

Alternative Hypothesis Ha
Then the Alternative Hypothesis (H_a) will be that Metro has been found to be significantly comfortable mode of transportation as compared to the other modes of transportation.

For Hypothesis No.5
Null Hypothesis H0
Here, H_0 (Null Hypothesis) assumed is that not much dent has been made towards safety so for as the introduction of Metro is concerned.

Alternative Hypothesis Ha
Thus, the Alternative Hypothesis will be that:-
A significant dent has been made towards safety so far as introduction of Metro is concerned.

Having developed above Hypotheses, chi-square test was envisaged to draw conclusions and to see whether the hypotheses were in alignment with the perceived perceptions of the metro passengers.

Research Design
Type of Research - Exploratory
Type of Sampling - Convenience sampling
Sample Size - 700 respondents
Data Collection – Through structured questionnaire
Statistical Tools Used - Chi-Square, mean and Proportion

Data Analysis and Interpretation
A questionnaire was issued amongst 700 persons of various ages, both males and female, who make use of the Delhi Metro network. The questionnaire pertained to aspects like saving in travelling time, comfort, safety, reduction in the number of vehicles on the roads, reduction in air pollution levels etc.

Out of 700 persons, 630 passengers reacted to the questionnaire information. Out of 630 passengers who reacted, 390 were males and 240 female passengers. Chi-square test was used to statistically arrive at the validity of the assumptions made by the researcher on these aspects. Quantitative analysis of the data received on these aspects has been discussed as below, using chi-square test:

KEY HYPOTHESES
Hypothesis No. 1 (H1)
H1.Has there been any reduction in the number of vehicles on the road on account of introduction of Metro network?

The data as obtained from the reactions of passengers received in response to questionnaire given to them and perceived by male and female was tabulated as under in Table – I.

Table 1-Reduction in Pollution Levels

	Very High	High	Moderate	O.K.	Low	
Male	165	108	45	36	36	390
Females	174	18	15	21	12	240
	339	126	60	57	48	630

The figures obtained against 5% reduction has been taken as low; while figures / answers as against 10% have been taken as 'O.K' and figures / answers as against 15% have been taken as 'moderate'.

Figures against 20% have been taken as 'High' while figures against 50% have been taken as 'very high'.

Null Hypotheses (H_O)
Let us assume that; There no significant reduction in the pollution levels on account of introduction of Metro. This will be looked upon as H_0 (Null Hypothesis).

Alternative Hypothesis (Ha)
Therefore, H_a (alternative hypothesis) will be that there is a significant reduction in the number of vehicles on the road on account of introduction of the Metro.

Now, Observed value (O) and Expected values (E), using chi-squaretest will be as shown in Table – II.

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Table – II

O	E	$\frac{(O-E)^2}{E}$
120	$\frac{180 \times 390}{630} = 111.4$	$\frac{(120-111.4)^2}{111.4} = 0.6$
60	$\frac{180 \times 240}{630} = 69$	$\frac{(60-69)^2}{69} = 1.2$
90	$\frac{144 \times 390}{630} = 70.5$	$\frac{(90-70.5)^2}{70.5} = 5.4$
54	$\frac{144 \times 240}{630} = 43.5$	$\frac{(54-43.5)^2}{43.5} = 2.5$
72	$\frac{132 \times 390}{630} = 81.6$	$\frac{(72-81.6)^2}{81.6} = 1.1$
60	$\frac{132 \times 240}{630} = 51$	$\frac{(60-51)^2}{51} = 1.6$
39	$\frac{84 \times 390}{630} = 51.9$	$\frac{(39-51.9)^2}{51.9} = 3.2$
45	$\frac{84 \times 240}{630} = 32.1$	$\frac{(45-32.1)^2}{32.1} = 5.2$
69	$\frac{90 \times 390}{630} = 57$	$\frac{(69-57)^2}{57} = 2.5$
21	$\frac{90 \times 240}{630} = 33$	$\frac{(21-33)^2}{33} = 4.4$

$$\sum \frac{(O-E)^2}{E} = 26.1$$

As $\sum \frac{(O-E)^2}{E} = 26.1$ is the computed value, let us call it as

Now, we may read the Tabulated value (T) from the chi-squaretable for degree of freedom (dof) = (r – 1) (k – 1) where r is the number of rows and k is the number of columns in the matrix.

Here, r = 2
And k = 5
dof = (r -1) (k – 1) = (2 – 1) (5 – 1) = 4

Now for a dof = 4 and α = level of significance = .05, we have,

T=9.488
the Tabulated Value as read from chi-squaretable
It can be seen that here, C > T.

Hence, we may reject the null – hypothesis.
This means that a significant reduction in the number of vehicles on the road on account of the introduction of Metro network was the correct assumption. We can thus interpret that the statistical data supports the assumption that a major dent has been created in reducing the number of vehicles by the introduction of this Metro network.

4.12 Hypothesis No. 2 (H2)
H2. Has there been a decrease in the air pollution level in the area around Metro Corridor used by a passenger?

The data on the aspect of air pollution reduction as perceived by males and females using Metro is tabulated below in Table-III.

Table 1-Reduction in Pollution Levels

	Very High	High	Moderate	O.K.	Low	
Male	165	108	45	36	36	390
Females	174	18	15	21	12	240
	339	126	60	57	48	630

The figures obtained against 5% reduction has been taken as low; while figures / answers as against 10% have been taken as 'O.K' and figures / answers as against 15% have been taken as 'moderate'.

Figures against 20% have been taken as 'High' while figures against 50% have been taken as 'very high'.

Null Hypotheses (H_o)
Let us assume that; There no significant reduction in the pollution levels on account of introduction of Metro. This will be looked upon as H_0 (Null Hypothesis).

Alternative Hypothesis (Ha)
Thus, H_a (alternative hypothesis) will be thatthere is a significant reduction in the pollution levels an account of introduction of Metro.

Now, observed values (O) and Expected Values (E) will be as shown in Table – IV.

Table-IV

O	E	$\frac{(O-E)^2}{E}$
165	$\frac{339 \times 390}{630} = 210$	$\frac{(165-210)^2}{210} = 9.6$
174	$\frac{339 \times 240}{630} = 129$	$\frac{(174-129)^2}{129} = 15.6$
108	$\frac{126 \times 390}{630} = 78$	$\frac{(108-78)^2}{78} = 11.5$
18	$\frac{126 \times 240}{630} = 48$	$\frac{(18-48)^2}{48} = 18.7$
45	$\frac{390 \times 60}{630} = 37.2$	$\frac{(45-37.2)^2}{37.2} = 1.63$
36	$\frac{57 \times 390}{630} = 35.4$	$\frac{(36-35.4)^2}{35.4} = 0.01$
21	$\frac{57 \times 240}{630} = 21.6$	$\frac{(21.6-21)^2}{21.6} = 0.016$
36	$\frac{48 \times 390}{630} = 30$	$\frac{(36-30)^2}{30} = 1.2$
12	$\frac{48 \times 240}{630} = 18$	$\frac{(12-18)^2}{18} = 2$

$$\sum \frac{(O-E)^2}{E} = 63.06$$

As $\sum \frac{(O-E)^2}{E} = 63.06$ is the computed value, let us call it as

Now, we may read the Tabulated Value (T) from the table of chi-squaretest for a level of significance at 5% and a degree of freedom=(r – 1) (k – 1) = (2 – 1) (5– 1) = 4 ; where r denotes number of rows and k denotes the number of columns.

T value with respect to α = level of significance = 0.05 and degree of freedom=4, we have as 9.488.

Thus, T = 9.488

We can see that, here, C > T. Hence we can reject the null – Hypothesis. This means that significant reduction in pollution levels has taken place on account of introduction of Metro.

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Statistical analysis of the data thus supports the view that a / significant reduction in pollution levels has been contributed by Metro network.

4.13Hypothesis No. 3 H3

H3. Has there been a saving in travel time by the introduction of Metro network in various areas?

The data as obtained from passengers (both male and female) as a result of their reactions in the questionnaire given to them has been tabulated and found to be as under in Table – V.

Table – V
Saving in Travel Time

	Very High	High	Moderate	O.K.	Low	
Male	144	114	54	27	51	390
Females	177	18	21	18	6	240
	321	132	75	45	57	630

The figures / answers obtained against 5% reduction has been taken as low; while figures / answers as against 10% have been taken as 'O.K' and figures / answers as against 15% have been taken as 'moderate' in the above matrix. Figures against 20% have been taken as 'high' and figures against 50% taken as 'very high'.

Null Hypothesis ; H0
From the above data, let us assume that;
There is no significant saving in travel time of the passengers now availing themselves of the Metro facility.

This assumption will be looked upon as Null Hypothesis (H_0).

Alternative Hypothesis Ha
Therefore, H_a (Alternative Hypothesis) will be that there is a significant saving in travel time of the passengers now availing themselves of this Metro facility.

Using chi-squaretest, observed value (O) and Expected value (E), will be as under in Table – VI.

Table – VI

O	E	$\frac{(O-E)^2}{E}$
144	$\frac{321 \times 390}{630} = 198.6$	$\frac{(144-198.6)^2}{198.6} = 15$
177	$\frac{321 \times 240}{630} = 122.4$	$\frac{(177-122.4)^2}{122.4} = 24.3$
114	$\frac{132 \times 390}{630} = 81.6$	$\frac{(114-81.6)^2}{81.6} = 12.9$
18	$\frac{132 \times 240}{630} = 51$	$\frac{(18-51)^2}{51} = 21$
54	$\frac{75x\ 390}{630} = 46.5$	$\frac{(54-46.5)^2}{46.5} = 1.2$
21	$\frac{75 \times 240}{630} = 28.5$	$\frac{(21-28.5)^2}{28.5} = 1.97$
27	$\frac{45 \times 390}{630} = 27.9$	$\frac{(27-27.9)^2}{27.9} = 0.03$
18	$\frac{45 \times 240}{630} = 17.7$	$\frac{(18-17.7)^2}{17.7} = 0.005$
51	$\frac{57 \times 390}{630} = 35.4$	$\frac{(51-35.4)^2}{35.4} = 6.9$
6	$\frac{57 \times 240}{630} = 21.6$	$\frac{(6-21.6)^2}{21.6} = 11.3$

$C = \sum \frac{(O-E)^2}{E} = 94.9$

T = 9.488

Now, Tabulated value (T) as obtained from chi-squaretable for level of significance = .05 and degree of freedom = (r -1) (k – 1) = (2 – 1) (5 – 1) = 4, is 9.488.

Thus, T = 9.488
Now, C is found to be > T.

Hence, we may reject the Null Hypothesis.
Therefore, the assumption that there is no significant saving in travel time of passengers is not a valid one. We can thus conclude that statistically, introduction of Metro network has been able to save the travelling time of the passengers.

Hypothesis No.4
H4.Has Metro been found to be a comfortable mode of travelling as compared to other modes of travelling?

The replies given by persons (both males and females) with respect to this aspect viz whether Metro travelling has been found to be a comfortable mode of travelling as compared to other modes of travelling were studied and tabulated. These replies are summed up as under in Table – VII.

Table – VII
Comfortable Mode of Travelling

	Very High	High	Moderate	O.K.	Low	
Male	156	111	60	45	18	390
Females	174	24	15	12	15	240
	330	135	75	57	33	630

The figures / answers obtained against 5% have been looked upon as low; while figures / answers as against 10% have been looked upon as 'O.K'. The figures / answers as obtained against 15% have been looked upon as 'moderate'. Figures against 20% have been taken as 'high'; while figures against 50% have been taken as 'very high'.

From the matrix as obtained above, researcher used the chi-squaretest to statistically arrive at the conclusion with respect to data obtained above

Null Hypothesis H0
Let us assume that the Null Hypothesis (H_0) is that;

Introduction of Metro has not been significant enough to be comfortable to the passengers as a mode of transportation.

Alternative Hypothesis Ha
Then the Alternative Hypothesis (H_a) will be that Metro has been found to be significantly comfortable mode of transportation as compared to the other modes of transportation.

Then Observed (O) and Expected (E) values as used in chi-squaretest will be as under in Table – VIII.

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Table – VIII

O	E	$\frac{(O-E)^2}{E}$
156	$\frac{330 \times 390}{630} = 182.4$	$\frac{(156-182.4)^2}{182.4} = 3.8$
174	$\frac{330 \times 240}{630} = 126$	$\frac{(174-126)^2}{126} = 18.3$
111	$\frac{135 \times 390}{630} = 84$	$\frac{(111-84)^2}{84} = 8.7$
24	$\frac{135 \times 240}{630} = 51$	$\frac{(24-51)^2}{51} = 14.3$
60	$\frac{75x\ 390}{630} = 46.5$	$\frac{(60-46.5)^2}{46.5} = 3.9$
15	$\frac{75 \times 240}{630} = 28.5$	$\frac{(15-28.5)^2}{28.5} = 6.4$
45	$\frac{57 \times 390}{630} = 35.4$	$\frac{(45-35.4)^2}{35.4} = 2.6$
12	$\frac{57 \times 240}{630} = 21.6$	$\frac{(12-21.6)^2}{21.6} = 4.3$
18	$\frac{33 \times 390}{630} = 21$	$\frac{(18-21)^2}{21} = 0.42$
15	$\frac{33 \times 240}{630} = 12$	$\frac{(15-14)^2}{12} = 0.75$

$$\sum \frac{(O-E)^2}{E} = 63.47$$

Thus, Computed Value (C) = 63.47

Now, for dof (degree of freedom) = (r -1) (k – 1) = (2 – 1) (5 – 1) = 4, and level of significance, α = .05, the value from the table = 9.488.

Thus,
T = 9.488

Now since C > T, the null hypothesis is rejected. We can therefore conclude that there is a significant difference made by Metro towards providing comfort to the passengers vis a vis earlier modes of transport.

The stastiscal inference as above tallies with the general perception of the researcher and others on this aspect.

Hypothesis No.5 H5
H5.Whether Metro travel is a safer mode of travel as composed to the earlier modes of travel used by passengers?

The reactions given by males and females in the questionnaire in regard to the dent made by Metro travel vis-à-vis other modes was also tabulated as under in Table – IX.

It was a safer mode of travel
Table – IX

	Very High	High	Moderate	O.K.	Low	
Male	150	120	60	30	30	390
Females	180	15	15	15	15	240
	330	135	75	45	45	630

While tabulating the above data, the response given by passengers against 50% was looked upon as 'very high'; while responses given against 20% were looked upon as 'high' and reopenses given against 15% were looked upon as 'moderate'. Similarly the responses given against 10% were treated as 'O.K' and responses given against 5% looked upon as 'low'.

Applying chi-square test to the data as in the matrix above, we find the values of Observed (O) and Expected (E) as below Table –X.

Null Hypothesis H0
Here, H_0 (Null Hypothesis) assumed is that not much dent has been made towards safety so for as the introduction of Metro is concerned.

Alternative Hypothesis Ha
Thus, the Alternative Hypothesis will be that:-
A significant dent has been made towards safety so far as introduction of Metro is Concerned.

Table – X

O	E	$\frac{(O-E)^2}{E}$
150	$\frac{330 \times 390}{630} = 204$	$\frac{(150-204)^2}{204} = 14.3$
180	$\frac{330 \times 240}{630} = 126$	$\frac{(180-126)^2}{126} = 23.1$
120	$\frac{135 \times 390}{630} = 84$	$\frac{(120-84)^2}{84} = 15.4$
15	$\frac{135 \times 240}{630} = 51$	$\frac{(15-51)^2}{51} = 25.4$
60	$\frac{75x\ 390}{630} = 46.4$	$\frac{(60-46.4)^2}{46.4} = 3.9$
15	$\frac{75 \times 240}{630} = 28.5$	$\frac{(15-28.5)^2}{28.5} = 6.4$
30	$\frac{45 \times 390}{630} = 27.9$	$\frac{(30-27.9)^2}{27.9} = 0.16$
15	$\frac{45 \times 240}{630} = 17.1$	$\frac{(15-17.1)^2}{17.1} = 0.26$
30	$\frac{45 \times 390}{630} = 27.9$	$\frac{(30-27.9)^2}{27.9} = 0.16$
15	$\frac{45 \times 240}{630} = 17.1$	$\frac{(15-17.1)^2}{17.1} = 0.26$

$$\sum \frac{(O-E)^2}{E} = 89.34$$

Now, the tabulated value for a degree of freedom = (r -1) (k – 1) = (2 – 1) (5 – 1) = 1 x 4 =4 and α = level of significance = .05 is given by

T = 9.488.
It is noticed here that C > T, we may reject the null hypothesis. In other words, chi-square test here concludes that large dent has been made by Metro towards safety in travelling. The statistical interpretation of the data goes to prove that Metro has been able to provide a more safer mode of transportation.

Outcomes of study
Thus, based on the above objectives of study and the statistical inferences the following findings are made-

A major dent has been created in reducing the number of vehicles by the introduction of this Metro network.

Introduction of Metro network has been able to save the travelling time of the passengers.

The statistical interpretation of the data goes to prove that Metro has been able to provide a safer mode of transportation.

There is a significant difference made by Metro towards

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providing comfort to the passengers vis a vis earlier modes of transport.

Conclusion

Thus, from the above discussion it can be inferred that by introduction of Delhi Metro there are multiple benefits that are met and will support in convenience, affordability, comfort, reducing pollution and above all helping passengers to save time and energy and also promoting opportunities for connectivity.

REFERENCE CRRI 2007 Delhi Transport Authority Delhi Metro Rail Corporation Kothari C.R, Research Methodology Pandey I.M Financial Management