CHAPTER SEVEN

ECONOMIC AND SOCIAL COST AND BENEFIT ANALYSIS

Description of economic benefits and costs of the Delhi Metro requires the identification of the changes brought out by it in the transport sector of the economy. Most importantly, DM contributes to the diversion of a very high proportion of current passenger traffic from road to Metro and serves part of the growing passenger traffic demand in Delhi. As a result, there will be a reduction in the number of buses, passenger cars and other vehicles carrying passengers on Delhi roads with the introduction of the Metro. There will be savings in travel time for passengers still travelling on roads due to reduced congestion and obviously also for those travelling by Metro. The Metro also brings about a reduction in air pollution in Delhi because of the substitution of electricity for petrol and diesel and reduced congestion on the roads. There will also be a reduction in the number of accidents on the roads.

The government needs to make a big initial investment for metro construction. The fixed cost for Phase I and Phase II is reported as Rs.14432 crore while the government also incurs the Operations and Management cost for day-to-day running of metro which is reported as Rs. 370.75 crore for 2011-2012. Investment in the Metro could result in the reduction of government investments on road developments and buses as also in the private sector investment on buses, passenger cars and other vehicles carrying passengers. There will be reductions in motor vehicles' operation and maintenance charges to both the government and the private sector. There could be cost savings to passenger car owners in terms of capital cost and operation and maintenance costs of cars if they switch over from road to Metro for travel in Delhi. The fare box revenue collections by Metro will be at the cost of the revenue, accruing earlier to private and the government bus operators and hence constitutes a loss in income.

The Delhi public will gain substantially with the introduction of the Metro service. It saves travel time due to a reduction of congestion on the roads and lower travel time of the Metro. There will be health and other environmental benefits to the public due to reduced pollution from the transport sector of Delhi. Land and house property owners gain from the increased valuation of house property prices due to the Metro. The Metro has the effect of increasing the income of the regional economy of Delhi vis a vis the rest of the Indian economy. Given that the per capita income of Delhi is far higher than the national per capita income, the redistribution of income in favour of Delhi may not be desirable from the point of view of income distribution in the Indian economy. The Metro provides employment benefits to the unskilled labour especially during its construction period. This labour is otherwise unemployed or under employed in the Indian economy.

This table describes the benefits and cost flows due to Metro.

7.1 BENEFIT AND COST FLOWS OF DELHI METRO INVESTMENT

Investment

Investment of Metro: Im

Investment reduced due to Metro

- Private buses: I_{bpri}
- Public buses: I_{bpub}
- Personal vehicles (cars and two-wheelers): I_{pv}
- Savings in Investment Cost of Road Infrastructure: I_{ri}

Operation and Maintenance (O&M) Charges

O & M charges of Metro: Om

O & M charges reduced due to Metro due to fewer vehicles on road and decongestion

- Private buses: O_{bpri}
- Public buses: O_{bpub}
- Personal vehicles (cars and two-wheelers): O_{pv}

Revenue

Revenue of Metro: R_m

Tax Revenue to Government: R_t

Revenue loss due to Metro

- Private buses: R_{bpri}
- Public buses: R_{bpub}

Benefits

Reduction in pollution: B_{pp}

- Due to reduction in number of vehicles on road
- Due to reduction in congestion on roads

Savings in travel time: B_{stt}

- Due to reduction on congestion on roads
- Due to reduction in travel time for Metro passengers

Reduction in accidents: B_{ra}

Foreign Exchange Costs and Benefits

Investment cost: I_{mf}

Savings in fuel cost: B_f

Various economic agents relevant for Metro could be identified as the government, passengers, transporters, general public and unskilled labour. Unskilled labour employed on the Metro gains to the extent of the difference between the project wage rate and the shadow wage rate. The social premium on investment and savings and foreign exchange accrue to the society represented by the General Public.

The flows of net economic benefits (NEB) of DM to the various economic agents could be computed as follows:

Government: $NB_g = (R_m + O_{bpub} + I_{bpub} + I_{ri} + R_t) – (I_m + O_m + R_{bpub} + R_t)$

Passengers: $NB_p = ((R_{bpri} + R_{bpub}) - R_m) + B_{st} + (I_{pv} + O_{pv}) + B_{ra}$

Transporters: $NB_t = O_{bpri} - R_{bpri}$

Unskilled labour: $NB_{ul} = (1 – PDUL) (I_{ml} + O_{ml})$

PDUL: Ratio of marginal productivity of labour and project wage rate

In the next section, we will estimate the monetary value of the above benefits.

7.2 SOCIAL BENEFITS

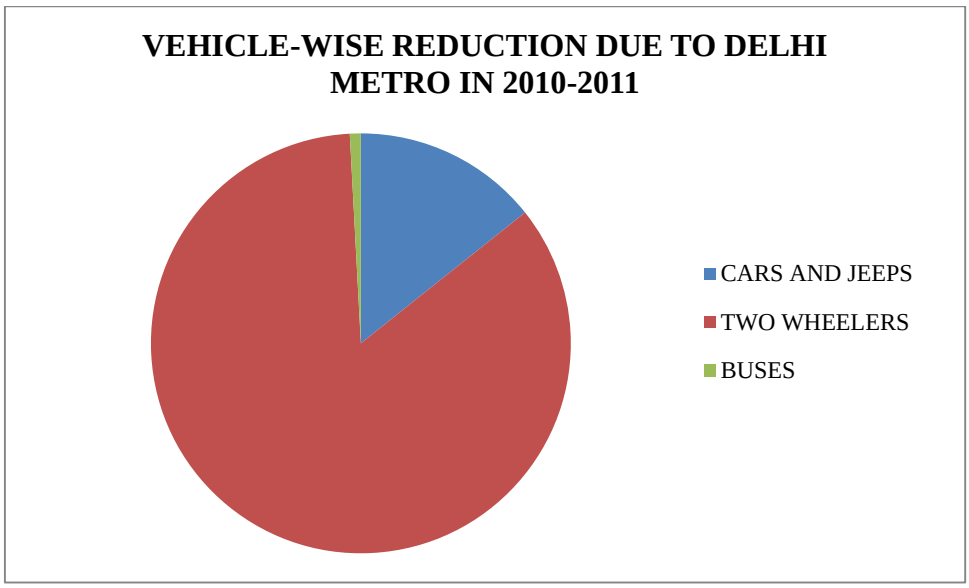
1) REDUCTION IN THE NUMBER OF VEHICLES ON ROAD

Based on the data given on Delhi Government's website, we estimate the growth rates of registered cars, two-wheelers and buses in Delhi are calculated as 9.8, 11 and 7 percent, respectively. To calculate the number of vehicles going off the road due to the introduction of MRTS the following exercise is conducted. The registered number of vehicles for each category of these vehicles in Delhi for the period 2002-42 is estimated using the above mentioned growth rates. RITES has reported that out of the total registered vehicles, only 28 percent of cars, 40 percent of two-wheelers and 65 percent of taxis and three wheelers are on the roads. It is also reported, depending upon the area and the density of population through which the Metro line passes, that only 30 percent of vehicles on road are influenced by Phase I of the Metro. It is further mentioned that 45 percent of cars, 70 percent of two-wheelers, and 25 percent of buses out of the influenced traffic are diverted to Metro. It is assumed that modes of transport like taxis and three wheelers are on the road by choice and hence they will not be diverted due to the Metro. Table reports estimates of diverted traffic to Metro (Phases I and II).

TABLE 7.1 REDUCTION IN VEHICLES DUE TO METRO (PHASE I & II)

YEAR	CARS AND JEEPS	TWO WHEELERS	BUSES	TOTAL
2011-2012	97493	458116	2871	558480

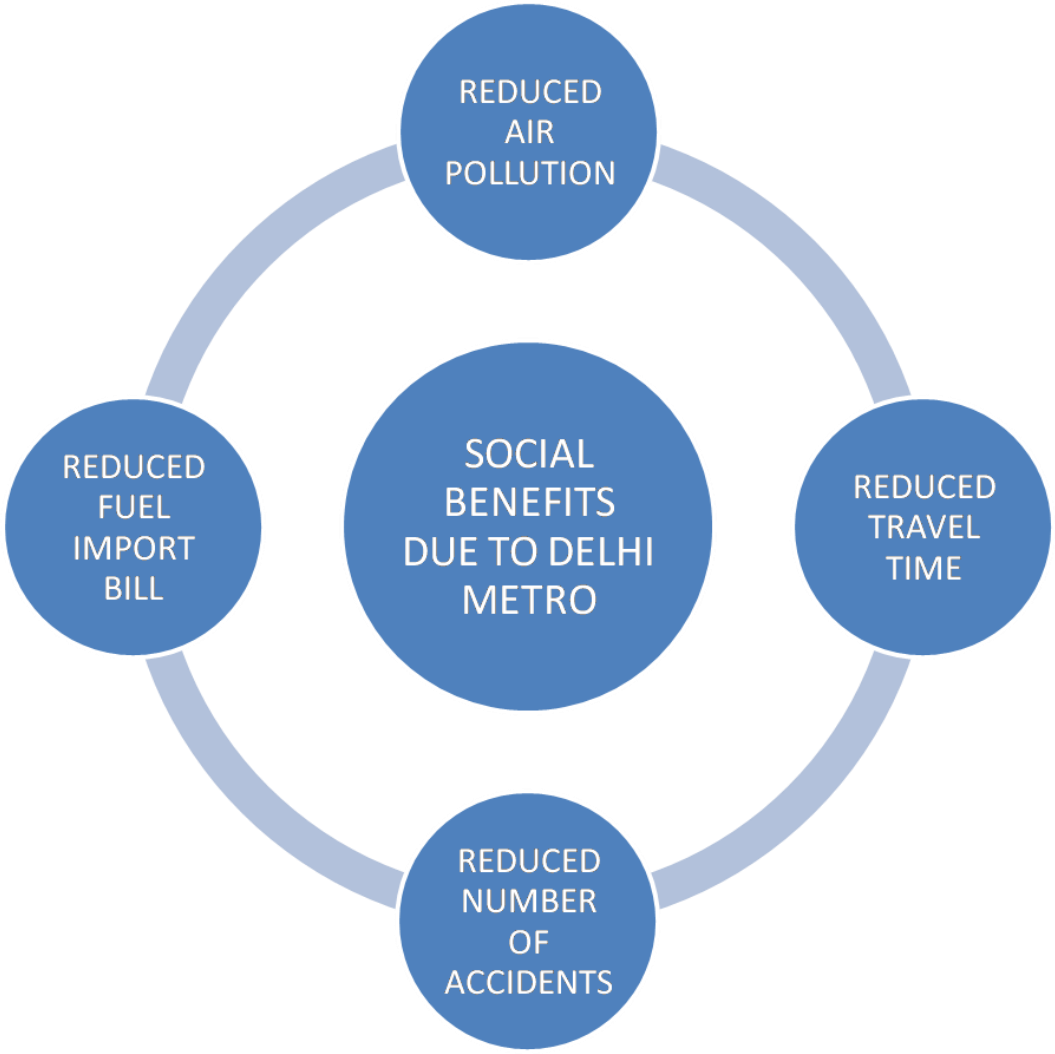
FIGURE 7.1 VEHICLE-WISE REDUCTION DUE TO DELHI METRO IN 2010-2011



The social benefits from the reduced number of vehicles on Delhi roads due to the Metro in economic terms could be identified as the following:

- Savings in Foreign Exchange due to reduced Fuel Consumption
- Reduction in Pollution
- Savings in Time for all passengers using Metro and Roads
- Savings in Accidents
- Savings in Vehicle Operating Cost (VOC) due to decongestion for residual traffic
- Savings in Capital and Operating cost of diverted vehicles
- Savings in the cost of Road Infrastructure

FIGURE 7.2 SOCIAL BENEFITS DUE TO DELHI METRO



2) SAVINGS IN PASSENGER TIME

The savings of travel time of passengers travelling by the Metro instead of by road are calculated as the product of the number of passengers travelled daily and the time saved on the average passenger lead in Delhi. In the case of residual passenger traffic on road, RITES has estimated the daily time saving by the passengers due to decongestion using the following formula:

$$T = \frac{D}{S_C} - \frac{D}{S_d}$$

where,

T: time saving on average daily run

D: daily run of vehicles (in km)

Sc: average speed in congested situation (without Metro).

Sd: average speed in decongested situation (with Metro)

The values of the parameters D, Sc, Sd for cars, buses, taxis, Two-wheelers and three-wheelers, along with the estimates of T for the first phase of the project are summarized in Table 1. On the basis of these values, the estimates of value of time/person travelling by buses or other vehicles are arrived .These are Rs. 5.96/hr and Rs. 7.91/hr, respectively. Passenger time saving per annum for mass transport is then calculated as the product of daily passengers carried, time saved on average lead on an annual basis and the value of time of metro passengers. In the case of other vehicles, the total time saving is given by the product of the total number of passengers on residual vehicles, time saving on average lead on an annual basis and value of time.

TABLE 7.2 VALUES OF PARAMETERS D, Sd, Sc AND T

MODE	D (Km)	Sd (Km/hr)	Sc (Km/hr)	T (hr)
Bus	209	14	10.5	4.98
Car	30	17	13	0.54
Taxi	80	17	13	1.45
Three-wheeler	100	17	13	1.81
Two-wheeler	25	17	13	0.45

TABLE 7.3 TIME SAVINGS AND VALUE OF TIME FOR PASSENGERS

	BUS	METRO
Daily passengers carried (million)	3.3	3.2
Time saved on average lead (hours)	0.21	0.31
Value of time per passenger (Rs.)	5.96	5.96
Value of daily time saving (Rs. Million)	4.13	5.91

Total monetary value of time saved is estimated as 4105 million rupees.

3) SAVINGS IN FUEL CONSUMPTION

There are savings in fuel consumption (inclusive of both CNG and petrol) due to the diversion of a part of the Delhi road traffic to Metro and reduced congestion to vehicles still operating on the roads. There is an inter-fuel substitution of petrol and CNG to electricity that could result in savings of foreign exchange and a

reduction of air pollution. Fuel saved due to traffic diverted to the Metro is estimated given the estimates of diverted traffic described above and the annual run and fuel consumption norms of different vehicles. Table provides information about the annual run and fuel consumption norms of different vehicles in Delhi. Based on the time savings estimated above, we can calculate the reduction in distance travelled due to congestion as Distance = Speed * Time. These numbers for cars, two-wheelers and buses come out to be 9.18 kms, 7.65 kms and 69.72 kms, respectively. The total reduction in CNG due to the traffic of buses diverted to the Metro (Phases I & II) during the year 2011-12 is calculated as 12.17 million kg. Similarly, the fuel saved due to the diverted traffic of cars and two-wheelers is estimated as 82.11 and 119.43 million litres respectively. When these fuel savings are valued the corresponding fuel savings for cars, two-wheelers and buses are Rs. 3121, 4539 and 219 million, respectively.

TABLE 7.4 ANNUAL RUN AND FUEL CONSUMPTION NORMS

TRAFFIC MODE	DIVERTED TRAFFIC	FUEL CONSUMPTION NORM	DAILY RUN	FUEL SAVINGS	VALUE OF FUEL SAVINGS (MILLION)
Cars	97493	13	30	82118786	3121
Two-wheelers	458116	35	25	119437450	4539
Buses	2871	18	209	12169089	219

Note: For cars and two-wheelers using petrol, price is Rs. 38/ltr

For buses using CNG, price is Rs. 18/Kg

FUEL SAVINGS DUE TO DECONGESTION

As explained in the previous section, estimates of reduction in distance travelled every day due to the decongestion effect are obtained for cars, two-wheelers and buses as 9.18 kms, 7.65 kms and 69.72 kms, respectively. Fuel savings due to decongestion can now be similarly calculated as above using appropriate fuel consumption norm.

TABLE 7.5 FUEL SAVINGS DUE TO DECONGESTION

TRAFFIC MODE	RESIDUAL TRAFFIC	FUEL CONSUMPTION NORM	REDUCTION IN DAILY RUN	FUEL SAVINGS	VALUE OF FUEL SAVINGS (MILLION)
Cars	119158	13	9.18	30712516	1167
Two-wheelers	196336	35	7.65	15663406	595
Buses	8614	18	69.72	12178186	219

There is an estimated total savings of 1981 million rupees due to reduction in fuel consumption because of decongestion. Overall there is a saving of 9859 million rupees in fuel consumption because of reduction in traffic and decongestion.

Fuel savings arising out of the Metro could result in the savings of foreign exchange for the Indian economy given that a very large proportion of domestic demand for petroleum products in India has been met out of imports.

4) REDUCTION IN AIR POLLUTION

Fewer vehicles and the decongestion for the residual traffic on Delhi roads due to Metro could lead to reduced air pollution. The distance saved due to decongestion is estimated by multiplying the time saved with the speed of a vehicle in a decongested situation. An estimate of the pollution reduction by a vehicle in this context could be obtained by multiplying the distance saved by the relevant emission coefficient for different pollutants for each category of vehicle. The emission coefficients for different vehicles as per the Euro II norms are given in Table 7.6. Estimates of reduction in distance traveled every day due to the decongestion effect are obtained for cars, two-wheelers and buses as 9.18 kms, 7.65 kms and 69.72 kms, respectively. Table 7.7 reports the estimates of air pollution loads due to decongestion avoided due to Metro.

TABLE 7.6 EMISSION FACTORS OF VEHICLES AS PER EURO II NORMS (Kg/Km)

	PM	NOx	HC	CO
Bus	0.00024	0.011	0.00087	0.0032
Car	0.00003	0.00015	0.00035	0.0022
Two-wheeler	0.00005	0.000075	0.001425	0.0015

TABLE 7.7 REDUCTION IN POLLUTION LOAD DUE TO DIVERTED TRAFFIC

REDUCTION IN POLLUTION LOAD	HC	PM	NOx	CO_2
Due to diverted traffic (in tonne)	1111	92	2512	2402
Shadow prices (Rs/tonne)	502	4777	6724	448
Value (Rs. Millions)	0.55	0.43	16.89	1.076

Overall, there is a saving of 19 million rupees because of reduction in pollution due to diverted traffic.

A recent study by Murty, Dhawla, Ghosh and Singh (2006) estimates the monetary value of reduction in air pollution due to Metro as the savings in the cost of pollution abatement due to the diverted traffic. The vehicular technology complying with Euro II norms or using CNG as a fuel could have similar effects on the air pollution in Delhi as estimated for the Metro. As such the cost of converting the diverted vehicles to Euro II norms is taken as the benefit which is estimated to be around 6883 million.

5) SAVINGS DUE TO FEWER ACCIDENTS

The Road User Cost Study (CRRI, 1982) later updated by Dr. L. R. Kadiyaliet. al. in association with the Loss Prevention Association of India provides estimates of the cost of various accidents on road. Components like gross loss of future output due to death/major injury, medical treatment expenses, legal expenses, and administrative expenses on police, insurance companies and the intangible psychosomatic cost of pain were included in the estimation. In the case of buses and other public vehicles, the loss due to lay off period and unproductive wages paid to the crew are also included. The costs under different heads are reported in the Table 7.8.

These studies have found that the following relationships exist between the number of vehicles affected and the number of persons killed and injured in road accidents.

$Y_1 = 49.43X + 750.42$ $R^2 = 0.89$

$Y_2 = 257.04X + 3181.41$ $R^2 = 0.90$

where,

X: number of vehicles affected in lakhs

Y_1: number of persons killed in road accidents in a particular year

Y_2: number of persons injured in road accidents in a particular year

TABLE 7.8 COMPENSATION VALUES

COST COMPONENT	VALUE (RS.)	REDUCTION IN INJURIES, DAMAGE TO VEHICLES	COMPENSATION (RS. MILLION)
Cost of fatal accident	437342	276	120.73
Cost of major accident	64256	1435.5	92.24
Cost of damage to cars in road accidents	9763	140	1.36
Cost of damage to two-wheelers	2286	658	1.5
Cost of damage to buses	32818	4.1	0.135

Assuming that the above relationships hold and given the number of vehicles that are expected to go off the road (diverted traffic) due to the Metro, the reduction in fatalities and accidents is estimated. For instance, in the year 2011-12, the diverted traffic for cars equals 97493, while the corresponding values for two-wheelers and buses are 458116 and 2871 respectively. The values of reduction in fatalities and injuries, as derived from the above equation are reported in Table above. The total benefit owing to the lesser number of fatalities and injuries is reflected in the total savings in compensation paid. Next, the study also reports the estimated relationship between the number of accidents resulting in damage to property and number of vehicles on road as,

$Y = 143.63X + 3345$ $R^2 = 0.84$

where,

X: number of vehicles on road in lakhs

Y: number of vehicles causing damage to property

Given the above relationship and the data on the mode wise distribution of accidents in Delhi over the years, the reduction in accidents for different types of vehicles is estimated and reported. The estimates of cost of damage to cars, buses and two-wheelers in road accidents, as reported in the above table are used to estimate the total savings in compensation paid due to damage caused vehicles as 216 million rupees.

7.3 ECONOMIC AGENTS AFFECTED BY METRO:

The economic agents affected by having the Metro operational in Delhi could be identified as government, passengers, general public, private transporters and unskilled labour. These agents get incremental benefits and incur incremental costs due to Metro.

The **Government** gets fare box revenues, revenues from property development and advertisements and tax revenue on the goods and services bought for the investments and operation and maintenance of the Metro while it suffers revenue losses due to the displaced public buses. It incurs the investment and operation and maintenance cost of the Metro while it saves the cost on road infrastructure and the capital and operating cost of displaced public buses. The net benefits for the government during the year 2011-12 are reported as Rs. 31760 million. There is also a reduction of 9859 million rupees in the annual fuel import bill.

The **Passengers** gain to the extent of the difference between the fares paid to buses in the absence of the Metro and the fares charged by the Metro. For instance, during the year 2011-12, the fare box revenue to the displaced buses should have been Rs. 10460 million while the annual report of Delhi Metro reports fare box revenue at Rs.12810 million. Therefore, passengers have incurred an additional cost of Rs.2350 million due to these fare differences. However, there is a time saving for the passengers due to the Metro. There is both time saving travelling on the Metro as also time saving to the residual traffic on the roads due to the reduced congestion. During the year 2011-12, these savings are together estimated as Rs.4105 million. There are also benefits due to a reduction in accidents to the passengers due to the functioning of the Metro, which are estimated as Rs 216 million during the year 2011-12. The net benefits to the passengers from the Metro are estimated as Rs.1971 million during the year 2011-12.

The **Private transporters** lose the revenue from displaced private buses but at the same time save on their capital and operating costs. These are estimated as Rs. 9410 and Rs. 6550 million, respectively resulting in a net loss of Rs. 2860 million to the private transporters during the year 2011-12.

The **Unskilled labour** employed on the construction and maintenance of Metro gain to the extent of the difference between the project wage rate and the wage rate in an alternative employment in India. Murty and Goldar provide an estimate of the marginal productivity of unskilled labour in agriculture as Rs. 48 while on the average, the industrial wage for unskilled labour in India is Rs. 120 per day. Assuming that the unskilled labour cost constitutes 5 percent of operation and maintenance cost of the Metro, the benefit to unskilled labour is estimated as Rs. 111 million during the year 2011-12.

The **General Public** not only benefits because of the government's reduced import bill but also because of the reduction in air pollution, the monetary value for which is estimated to be 6900 millions.

7.4 FINANCIAL ANALYSIS OF DELHI METRO

Assuming the costs of investment are equal among the various projects, the project with the highest IRR would probably be considered the best and undertaken first.

TABLE 7.9 CALCULATIONS OF NPV AND IRR

Year	Total Rev	PV (10%)	PVF (10%)	PV (20%)	PVF (20%)	PV (24%)	PVF (24%)
2015	2049.04	0.9091	1862.78153	0.8333	1707.46436	0.8065	1652.55011
2016	2129.73	0.8264	1760.00856	0.6944	1478.88425	0.6504	1385.176144
2017	2618.33	0.7513	1967.15348	0.5787	1515.22923	0.5245	1373.31559
2018	2723.86	0.683	1860.39623	0.4823	1313.71757	0.423	1152.192687
2019	2837.99	0.6209	1762.10559	0.4019	1140.58663	0.3411	968.0370725
2020	2961.66	0.5645	1671.85555	0.3349	991.859033	0.2751	814.7519256
2021	3637.64	0.5132	1866.83742	0.2791	1015.26564	0.2218	806.8288006
2022	3802.01	0.4665	1773.63904	0.2326	884.348212	0.1789	680.1801168
2023	3981.92	0.4241	1688.73197	0.1938	771.695957	0.1443	574.5909525
2024	4179.52	0.3855	1611.20533	0.1615	674.992634	0.1164	486.4962387
2025	5126.94	0.3505	1796.99277	0.1346	690.086241	0.0938	480.9070535
2026	5391.95	0.3186	1717.87645	0.1122	604.977207	0.0757	408.1708964
2027	5687.50	0.2897	1647.66933	0.0935	531.781437	0.061	346.9376221
2028	6017.90	0.2633	1584.51387	0.0779	468.794645	0.0492	296.0808287
2029	7370.57	0.2394	1764.51342	0.0649	478.349711	0.0397	292.6114564
2030	7822.92	0.2176	1702.26709	0.0541	423.219896	0.032	250.333395

	Total		28038.5476		14691.2527		11969.16089
	Intial investment		14432		14432		14432
	NPV		13606.5476		259.25265		-2462.839111

CALCULATION OF NPV AND PI

Initial Cost of Metro is Rs. 14432 crores.

NPV = PV of cash flows – Initial Investment

Since market rate is 10%, NPV is calculated at 10%

Calculation of cash flows at market rate of 10% is done in excel sheet

Sum of PV of cash flows at 10% = Rs. 28038.54763

So, NPV = 28038.55 – 14432 = 13606.55

Profitability index = PV of future cash flows/Initial investment

= 28038.55/14432 = 1.94

If PI > 1 than project is profitable

Therefore, PI is 1.94

This is profitable.

CALCULATION OF FINANCIAL IRR

At IRR, NPV = 0

NPV at 20% = 259.2526501

NPV at 24% = -2462.83911

Therefore, IRR by interpolation

IRR = 20.381%

Since, PI value is greater than 1, therefore, Delhi Metro is a profitable venture to operate. Also, the internal rate of return for this project comes out to be around 20.38%. Thus, Delhi Metro is a financially viable investment.