India

2015 Ex-Post Evaluation of Japanese ODA Loan Project

"Delhi Mass Rapid Transport System Project Phase 2 (I) - (V)"

External Evaluator: Yumiko Onishi, IC Net Limited

0. Summary

The Project aimed to reduce traffic congestion and pollution by constructing a mass rapid transport system in the National Capital Territory of Delhi (NCTD) that faced problems of economic loss and air pollution due to traffic congestion caused by rapid economic growth and urbanization since the 1990s. From the time of the appraisal to the ex-post evaluation, the urban transport sector continues to occupy an important position in development plans of the governments of India and the NCTD. The development need for a rapid transport system was seen at the times of both the ex-post evaluation and the appraisal. The Project is also in line with Japan's ODA policy, and thus, the relevance of the Project is high. Both the Project cost and Project period exceeded the plan. Therefore, the Project's efficiency is fair. Although some scopes have been added to the Project after its commencement, they were found to be appropriate. Most of the operational and effect indicators set at the time of the appraisal have achieved their targets. With regard to impact on such aspects as regional economic development and improving the urban environment, the Project made a certain degree of contribution. Thus, the effectiveness and impact of the Project are determined to be high. Delhi Metro Rail Corporation (DMRC), the Project's executing agency that has also been responsible for operation and maintenance (O&M), has the institutional structure to operate and maintain the Project as well as necessary technical skills. With regard to the financial status of DMRC, continuous efforts are required for improvement, but no serious issues are found. At the time of the ex-post evaluation, O&M are conducted properly and the sustainability of the Project is high.

In light of the above, the Project is evaluated to be highly satisfactory.

1. Project Description

Project Location

Line 5 of Delhi Metro

1.1 Background

In India, the urban population increased from 217 million in 1991 to 285 million in 2001, and it was expected to grow further. While urbanization was proceeding rapidly, public transport infrastructure was not developed sufficiently. At the time of the appraisal for the Project, the population owning vehicles and two-wheelers was growing at a high rate of 12% per annum. Moreover, the ratio of population using public transport in urban areas decreased from 69% in 1991 to 55% in 2001, aggravating traffic congestion. Particularly in large cities such as Delhi and Bangalore, the congestion was worsening due to increasing demand on road transport. Health problems, arising out of air and noise pollutions from the vehicles along with economic loss, have become a serious issue. To reduce the traffic congestion and automobile-related pollution, it was necessary to develop a large-scale public transport system based on urban development plans.

1.2 Project Outline

The objective of the Project was to cope with the growing traffic demand in the Delhi metropolitan area, the capital city of India, by extending the mass rapid transport system totaling approximately 83 km in length, thereby contributing to the regional economic development and improvement of the urban environment through alleviation of traffic congestion and reduction of traffic pollution.

Loan Approved Amount/ Disbursed Amount	I.	14,900 million yen / 14,899 million yen	
	II.	13,583 million yen / 13,582 million yen	
	III.	72,100 million yen / 72,100 million yen	
	IV.	77,753 million yen / 76,543 million yen	
	V.	33,640 million yen / 30,312 million yen	
Exchange of Notes Date/ Loan Agreement Signing Date	I.	March 2006 / March 2006	
	II.	March 2007/ March 2007	
	III.	March 2008 / March 2008	
	IV.	March 2009 / March 2009	
	V.	March 2010 / March 2010	
Terms and Conditions	I/II	Interest Rate	1.3%
		Repayment Period	30 years
		(Grace Period)	(10 years)
		Conditions for Procurement:	General untied
	III/IV	Interest Rate	1.2% (Main portion), 0.01% (Consultancy)
		Repayment Period	30 years
		(Grace Period)	(10 years)
		Conditions for Procurement:	General untied
	V	Interest Rate	1.4% (Main portion) 0.01% (Consultancy)

	Repayment Period: 30 years (Grace Period): (10 years) Conditions for Procurement: General untied
Borrower / Executing Agency	The President of India/Delhi Metro Rail Corporation Limited
Final Disbursement Date	June 2015
Main Contractors (Over 10 billion yen. The list of contractors with more than 1 billion yen is attached at the end of the report.)	・ Dywidag-Systems International GmbH (Germany)/Ircon International Ltd. (India)/Larsen & Toubro Ltd. (India)/Shimizu Corporation (Japan)/Samsung C&T Corporation (South Korea) ・ Soma Enterprise Limited (India)/Continental Engineering Corporation (Taiwan) ・ Bombardier Transportation GmbH (Germany)/Bombardier Transportation India Ltd. (India) ・ ITD Cem (India)/Italian-Thai Development Public Company Limited (Thailand) ・ BEML Limited (India)/Mitsubishi Electric (Japan)/Mitsubishi Corporation (Japan)/Hyundai Rotem (South Korea)
Main Consultants (Over 100 million yen)	Rail India Technical and Economic Services Ltd (India)/Oriental Consultants Global Co. Ltd. [1] (Japan)/Japan Railway Technical Service (Japan)/Tonichi Engineering Consultants, Inc (Japan)/Oriental Consultants Co. Ltd. (Japan)/Parsons Brinckerhoff International, Inc. (USA) (JV)
Feasibility Studies, etc.	Executing agency prepared the feasibility study in 2005.
Related Projects	<u>Japanese ODA Loan</u> Delhi Mass Rapid Transport System Project Phase 1 (I)-(VI) (February 1997, March 2001, February 2002, March 2003, March 2004, March 2005) Delhi Mass Rapid Transport System Project Phase 3 (I) (II) (March 2012, March 2014) Bangalore Metro Rail Project (I)(II) (March 2006, June 2011) Chennai Metro Project (I)-(IV) (November 2008, March 2010, March 2013, March 2016) Kolkata East-West Metro Project (I) (II) March 2008, March 2010) Mumbai Metro Line III Project (September 2013) Ahmedabad Metro Project (March 2016) <u>Dispatch of Experts (JICA)</u> Rolling Stock Maintenance (2007-2008) Operational Safety (2007-2008)

[1] It was originally Oriental Consultants; however was split and became Oriental Consultants Global in 2014.

2. Outline of the Evaluation Study

2.1 External Evaluator

Yumiko Onishi, IC Net Limited

2.2 Duration of Evaluation Study

Duration of the Study: December 2015 – January 2017

Duration of the Field Study: March 7–21, 2016 and June 20–24, 2016

3. Results of the Evaluation (Overall Rating: A[2])

3.1 Relevance (Rating: ③[3])

3.1.1 Relevance to the Development Plan of India

At the time of the Project appraisal, to deal with traffic congestion due to increasing demand on road transport, economic loss and health hazards due to air and noise pollutions from vehicles in large cities like Delhi, the Government of India had given priority to development of the urban transport sector as described in the *Tenth Five Year Plan* (2002–2007). At that time, the *Master Plan for Delhi 2001* (MPD 2001) was approved in the Project target area of National Capital Territory of Delhi (NCTD), and a rapid transport system was planned. The *Master Plan for Delhi 2021* (MPD 2021), which was subsequently approved by the Government of India in February 2007, also emphasized the importance of a rapid transport system as the core means of transport in the NCTD.

The importance of a rapid transport system in India and Delhi remains the same at the time of the ex-post evaluation. The *Twelfth Five Year Plan* (2012–2017) regards public transport including metro projects as one of the pillars that make up India's cities in the future, and aims to increase the share of public transport to more than 50%. As can be seen, from the time of the appraisal to the ex-post evaluation, the Project is in line with the development plans of the Government of India and the Government of NCTD.

3.1.2 Relevance to the Development Needs of India

As mentioned earlier, at the time of the Project appraisal, Delhi faced the issue of chronic traffic congestion and other problems associated with it. The average vehicular speed was said to be 15 km/hour at that time, and the urban transport network's dependency on roads was reaching its limit, indicating strong development needs for the Project.

Delhi Metro has seen an annual average ridership increase of approximately 8%, and the Project seems to have contributed to reducing traffic congestion and air pollution to some extent (see "3.4 Impact" for details). At the same time, the population having four wheelers and two

[2] A: Highly satisfactory, B: Satisfactory, C: Partially satisfactory, D: Unsatisfactory

[3] ③: High, ②:Fair, ①: Low

wheelers continues to increase even at the time of the ex-post evaluation, and the air pollution has become a serious issue. According to the World Health Organization (WHO), the level of PM 2.5 in Delhi in 2013 was 198 μg/m^3, about twenty times higher than the permissible limit (10 μg/m^3) set by the WHO. The Government of the NCTD implemented a vehicle restriction for 15 days in January and April 2016 and is considering regular enforcement of such restriction. Because of such restrictions, more people are expected to turn to public transport. Construction of the "Delhi Mass Rapid Transport System Project Phase 3" has also been underway since 2012. Development of public transport infrastructure is still needed in Delhi, and the Project is in line with the development needs at the time of the ex-post evaluation as well.

3.1.3 Relevance to Japan's ODA Policy

In the *Medium-Term Strategy for Overseas Economic Cooperation Operations* (2005) that was in effect at the time of the appraisal, development of economic infrastructure and resolving environmental problems were mentioned as important areas for India. In addition, the *Country Assistance Strategy for India* of 2005 also included urban transport as a core sector for assistance to India. It stated that assistance will be provided for urban transport infrastructure (including flyovers and bridges), particularly a mass rapid transport system, as they contribute to reducing traffic congestion and enhancing environmental protection by such means as reducing air pollution. In JICA's country analysis paper prepared in March 2012, the need for a large-scale public transport system based on urban development plans is pointed out to reduce traffic congestion and vehicle-related pollutions.

The Project has been highly relevant to the development plans and needs of India and Delhi as well as Japan's ODA policy. Therefore, its relevance is high.

3.2 Efficiency (Rating: ②)

3.2.1 Project Outputs

Civil works and procurement of rolling stocks

The Project is Phase 2 of the Mass Rapid Transport System Project in the NCTD. Originally, at the time of the appraisal in 2006, out of the 245 km network, it was to construct five lines comprising of six different sections (53.02 km long in total). Subsequently in 2008, the Central Secretariat – Qutub Minar section of Line 2 was extended to the Haryana State border and Line 6 was added to the Project's scope. As a result, a total length of 82.80 km has been constructed (see Attachment 1 for the metro network). Table 1 shows the outputs of the Project. The additional portion was included in the Project in view of the Commonwealth Games held in 2010. The network was to be used as public transport connecting the Games venues and major commercial areas in the city. Moreover, the construction of Line 6 was planned from the beginning. However, because the introduction of first ever standard gauge in the country was

being considered and its technical appraisal took time, Line 6 was included only after the Project started. With the changes in the network, the required number of rolling stocks has also increased from 312 to 734 coaches and the number of depots from one to four.

Table 1: Metro Line and Sections Covered by the Project

Line	Section	Type	Length (km)	
			Plan (2006)	Actual (2012)
1 (red)	Shahdara – Dilshad Garden	Elevated	3.09	3.09
2 (yellow)	Central Secretariat – Haryana State border (originally Qutub Minar)	Elevated	2.89	8.74
		Underground	7.98	11.76
	Vishwa Vidyalaya – Jahangirpuri	Elevated	5.42	5.20
		Underground	0.94	1.16
3 (blue)	Indraprastha – New Ashok Nagar	At grade	1.85	1.85
		Elevated	6.22	6.22
4 (blue)	Yamuna Bank – Anand Vihar	Elevated	6.16	6.16
5 (green)	Kirti Nagar – Mundka, Ashok Park – Inderlok	Elevated	18.47	18.46
6 (violet)	Central Secretariat – Badarpur	Elevated	—	14.06
		Underground	—	6.10
Total			53.02	82.80

Source: DMRC

The major changes to the Project output from the original plan are the extension of Line 2 and the inclusion of Line 6. In view of the Commonwealth Games, these lines were to be constructed from the beginning, and their inclusion into the Project is considered appropriate. With regard to the gauges, because Indian Railways uses broad gauges, all of Phase 1 and the plan for Phase 2 were in broad gauges. However, the introduction of standard gauge was debated from the time of Phase 1 appraisal. Compared to broad gauge, its project cost can be lower and other metro projects in the world are using standard gauge. Considering these points and that the use of standard gauge would enable the Project to leverage technical advancement, the change of gauge is considered appropriate.

Consulting Service

Consulting service for the Project included review of design, assisting in procurement procedures (civil works of the underground portion financed by the ODA Loan), supervision of works, quality control, safety management, implementing safety training program, assisting in trial run and review of operation and maintenance manuals. Initially, 1,922 man/months (M/M) was allocated for the consulting service. However, because the Delhi Metro Rail Corporation (DMRC) has developed internal human resources through the implementation of Phase 1, the dependence on external experts has decreased, and only 1,789 M/M was used. In Phase 1, the

consultants supervised the civil works, but DMRC personnel performed the same task in Phase 2, and the consultants have provided advisory services.

3.2.2 Project Inputs

3.2.2.1 Project Cost

Table 2 compares the planned and actual total Project costs and the Japanese ODA Loan portion. Since the scale of the Project is large, ODA Loan was provided each year from FY 2006 to 2010 and the plan, including the project cost, was revised each time. Therefore, to compare the planned and actual project cost, the sum of cost from 2006 appraisal and cost of scopes additionally included in 2008 appraisal was used as the plan[4]. This has resulted in project cost to be above the plan as the total cost was 112% against the plan, and ODA Loan portion was 127%. The ODA Loan was mainly used for the civil works of the underground portion, electrical and telecommunication works, and procurement of rolling stocks. The main reasons for actual project cost exceeding the plan was rise in the price of rolling stocks and eventual increase in final number of rolling stocks procured. When compared to the plan made in 2006 appraisal, the output has increased; however, as already described in section 3.2.1, the addition of scope was appropriate and the resulting change in project cost is also appropriate.

Table 2: Planned and Actual Project Cost

	Planned	Actual	Achievement
Project Cost	338,782 million yen	379,866 million yen	112%
ODA Loan Portion	162,955 million yen	207,438 million yen	127%

Source: Prepared by the External Evaluator based on documents provided by JICA and DMRC

For financing the Project, other than Japanese ODA Loan, contributions from the Government of India, the governments of NCTD and Haryana State and DMRC were planned. The ODA Loan makes up 55% of the total Project cost, DMRC accounts for 6%, and the rest were provided by the central and state governments. The Project did not encounter problems such as delay in providing finance.

3.2.2.2 Project Period

The Project period was originally planned to be from March 2006, the time of the Loan Agreement, to November 2010, when all the corridors were to be in commercial operation, totaling 4 years and 9 months (57 months). Table 3 shows the dates of commercial operation

[4] The project cost in 2006 appraisal plan was JPY 188,377 million (out of which JPY 90,673 million was ODA Loan) and the project cost in 2008 appraisal plan for additional scope was JPY 150,405 million (out of which JPY 72,282 million was ODA Loan).

commencement for the sections constructed under the Project. The Project was completed in August 2011[5]. This makes the Project period 5 years and 6 months (65 months), which is 114% against the plan.

Table 3: Dates of Commercial Operation Commencement of Lines in the Project

Line	Date of Commercial Operation Commencement
1	June 2008
2	Central Secretariat – Haryana State border: June 2010 (partial), September 2010 (whole)
	Vishwa Vidyalaya – Jahangirpuri: February 2009
3	May 2009 (partial), November 2009 (whole)
4	January 2010
5	April 2010 (partial), August 2011(whole)
6	October 2010 (partial), January 2011 (whole)

Source: DMRC

In Delhi, the Commonwealth Games took place in October 2010 and the Project targeted to complete the corridors so as to serve as public transport system for the event. Although part of the related corridor for the Games was commissioned before the event, there was eight months delay for the Project as a whole, because the standard gauge was introduced for the first time in India and time was required for redesigning of tracks and stations. Most of the corridors under the Project have been completed by the original target of November 2010. The rest of the corridors were total of 8.13 km that comprises portions of Line 5 and 6.

In the Project, although the Project period was set considering the Commonwealth Games, the delay was caused mostly due to change in size of the gauge. Because the project period was planned with due consideration to using the standard gauge, the actual Project period is not necessarily relevant to the output.

3.2.1 Results of Calculations of Internal Rates of Return (Reference only)

Financial Internal Rate of Return (FIRR)

FIRR calculated in the 2010 appraisal was 3.04%. As assumptions for calculating FIRR, the cost included the project and operation and maintenance (O&M) costs while the benefit included revenues from fares, advertisement and property development. The project life was set for 30 years. For recalculation of FIRR at the time of the ex-post evaluation, basically the same parameters were used. However, at the time of the appraisal, the fare structure was assumed to remain the same for the course of the project life, which seemed inconceivable, and there was an indication of fare revision at the time of the ex-post evaluation. Therefore, recalculation was

[5] Consulting service was completed in June 2012.

made with the assumption that the fare will increase by 15% every four years from 2017. As a result, the recalculated FIRR is 3.84%[6].

Economic Internal Rate of Return (EIRR)

For calculating EIRR, the following assumptions were made: the cost involved the project and O&M cost excluding the taxes; the economic benefit included savings from the vehicle operating cost, the road and metro passenger travel time, the operating cost of buses and other transport systems from reduced traffic, and reduction in accidents and pollutions. EIRR at the 2006 appraisal was 22.70% but the figure does not include the addition to the Project scope. EIRR in 2010, including the final scope, was 13.72%. The recalculated EIRR at the time of the ex-post evaluation is 25.61%[7].

Both the Project cost and the Project period exceeded the plan. Therefore, the efficiency of the Project is fair.

3.3 Effectiveness[8] (Rating: ③)

3.3.1 Quantitative Effects (Operation and Effect Indicators)

Effectiveness was evaluated with weight on basic operational and effect indicators for the railway projects set at the time of appraisal, namely operating rate, running distance, number of running trains per day, volume of transportation and income from the passengers. Table 4 shows the planned and actual figures of operational and effect indicators for the Project. For the Project, the target year is two years after the completion of the project, and therefore, for comparison, figures from two years after the project completion, which was 2013, were used.

[6] FIRR is improved as a result of recalculation; however, fare increases are set only to meet the rising operation and maintenance cost and price increase above the initial estimation and therefore, fare increases are not the factor for the higher FIRR

[7] EIRR is much higher than the one at the time of the appraisal because the saving from travel time at the time of the ex-post evaluation was found to be several times the one in 2010. At the time of the ex-post evaluation, the assumptions employed for the saving from travel time were that there is an economic benefit of INR 0.75/minute and that there is 12.67 minutes of saving for every 8 km of travel. Nevertheless, the difference in EIRR figures may have been the result of methods of calculation because the assumptions used for the appraisal could not be confirmed. On the other hand, if the 2006 appraisal figure is taken for comparison, it is fair to say that the Project has brought more economic benefit than expected.

[8] Sub-rating for Effectiveness is to be made with consideration of Impact.

Table 4: Planned and Actual Operational and Effect Indicators

	Target	Actual		
	2012	2011	2013	2015
	2 years after completion	Completion year	2 years after completion	4 years after completion
Operating rate (%/year)	94	94	94	94
Running distance (thousand km/day)	144.50	183.69	202.92	236.01
Line 1	5.93	6.22	6.24	7.66
Line 2 (Central Secretariat – Haryana State border)	40.09	101.95	115.37	129.51
Line 2 (Vishwa Vidyalaya – Jahangirpuri)	20.30	15.97	18.38	19.11
Line 3	12.64	12.62	13.79	17.20
Line 4	5.62	9.84	10.49	13.21
Line 5	26.62	11.35	10.78	10.67
Line 6	33.30	25.74	27.87	38.65
No. of running trains per day in 2 directions (X = peak hour frequency)	4,048	3,991	4,531	4,463
Line 1	480 (X=2.5)	462 (3.83)	498 (3.70)	521 (3.25)
Line 2 (Central Secretariat – Green Park)	456 (X=2.75)	668 (2.67)	657 (2.63)	667 (2.67)
Line 2 (Green Park – Haryana State border)	228 (X=5.5)	460 (2.67)	439 (2.63)	422 (2.67)
Line 2 (Vishwa Vidyalaya – Jahangirpuri)	456 (X=2.75)	451 (4.0)	451 (3.95)	424 (4.0)
Line 3(Indraprastha – Yamuna Bank)	456 (X=2.75)	668 (2.67)	651 (2.67)	688 (2.5)
Line 3 (Yamuma Bank – New Ashok Nagar)	228 (X=5.5)	331 (5.33)	328 (5.33)	345 (5.2)
Line 4	228 (X=5.5)	334 (5.33)	323 (5.33)	343 (5.2)
Line 5 (Ashok Park – Mundka)	416 (X=3)	402 (4.2)	381 (4.63)	389 (4.3)
Line 5 (Kirti Nagar – Ashok Park)	208 (X=6)	202 (8.4)	191 (9.27)	201 (8.57)
Line 5 (Inderlok – Ashok Park)	208 (X=6)	200 (8.4)	190 (9.27)	188 (9.27)
Line 6	416 (X=3)	327 (5.0)	354 (3.73)	491 (3.3)
Volume of transportation (million people km/day)	18.29	21.56	28.78	35.89
Income from passengers (INR million/day)	23.07	21.56	33.83	42.25

Source: DMRC

The operating rate has achieved its target. Running distance as a whole is 202,920 km/day against the target of 144,500 km/day and the number of running trains is 4,531 trains/day and

exceeded the target. Line 2 between Central Secretariat and Haryana State Border and Line 4 in particular have a large number of passengers because they cater to east Delhi that has many residential areas and connect Gurgaon and central Delhi. This has resulted in greatly exceeding the originally projected demand. By contrast, Line 5 has a limited number of passengers, and its daily running distance remains 40% of the target while frequency during the peak hours is also around 9 minutes. The volume of transportation and the income from passengers have also exceeded the targets.

For reference, ridership for the Project should be also explained. The ridership target for the Project inclusive of Phase 1 corridor two years after the Project completion was estimated at 2,980,000 people a day. However, the ridership in 2013 was 1,930,000 and the one in 2015 was 2,360,000. One of the reasons for ridership not reaching the target is the limited availability of the feeder bus services[9]. In addition, some buses operated by Delhi Transport Corporation (DTC) run parallel to the metro and the competition has kept the ridership of the metro from increasing.

All the basic operational and effect indicators set in the planning stage have achieved their targets. Except for the issue of ridership which was used for the evaluation as reference, the Project is evaluated to have brought originally expected effects.

3.3.2 Qualitative Effects

The expected qualitative effects of the Project were improved access to public transport, safety and security of metro operation, and improved services. In the ex-post evaluation, a beneficiary survey was conducted targeting mainly the Delhi Metro passengers. Through the survey, the qualitative effects and impact of the Projects were studied. Questionnaire interviews with 124 passengers were conducted at the Kailash Colony Station (Line 6) and the Noida Sector 16 Station (Line 4), both of which were selected randomly from the 79 stations constructed under the Project. In addition, interviews were conducted with residents (26 households) and business establishments (6 establishments) along the metro corridor. For the survey on residents, in addition to the two locations where the survey was conducted for the metro passengers, Punjabi Bagh Station and New Ashok Nagar Station were selected. Attachment 2 explains the sampling method and the results of the beneficiary survey in detail[10].

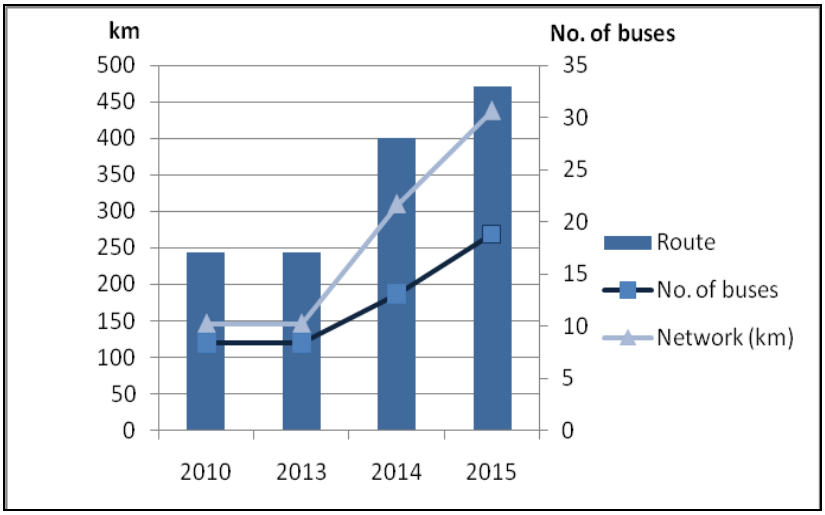
[9] Service of transporting passengers who are away from a metro station in order to promote the use of the metro.

[10] As a supplementary means to grasp the effect of the Project, questionnaire surveys were conducted targeting a) metro passengers (124 people), b) residents along the metro corridor (26 households) and c) business establishments along the metro corridor (6 establishments). A passenger survey was conducted during the peak hours on weekdays, and off-peak hours on weekdays and a holiday (Sunday). Three enumerators were assigned at the exit gate and sampled passengers every five minutes. The characteristics of passengers vary depending on the locality and the station. The survey does not necessarily reflect the whole picture of passengers because only a limited number of samples was taken. Moreover, best effort was made to sample the respondents to minimize selection bias; however, self-selection bias was unavoidable because some of the passengers declined to take part in the survey as they were in a hurry particularly during the peak hours (out of the 286 passengers who were approached for the survey, 124 took part in the survey). Hence, the off-peak hours on weekdays had the highest rate of responses. Gender-wise number of

Improved access to public transport

In the beneficiary survey, 69% (86 respondents) of the passengers replied that they use the metro on a daily basis. Ninety percent (111 respondents) said that, by using the metro, their travel time has reduced, indicating that the metro has become an important mode of transport for the people of Delhi.

On the operation of feeder buses, which aims to provide better access for passengers to their nearest station, DMRC started with 17 routes in 2010. The feeder bus network started expanding in 2014 and there are now 33 routes enabling passengers to use the service at 53 out of the 138 stations (excluding the Airport Express Line) constructed under Phase 1 and Phase 2 of the Project. Figure 1 below shows the changes in the feeder bus services.



Source: DMRC

Figure 1: Changes in Feeder Bus Services

Feeder buses have the service coverage of 5–8 km radius from the metro station. The rationalization of the route and the establishment of a new route are decided on the basis of the population density and socioeconomic condition (such as occupation and income) of the area. The operation of feeder buses is to be expanded to 69 routes as the metro network expands with the implementation of Phase 3 of the Project. There are buses operated within the city by DTC; however, they do not exclusively operate as feeder for the metro. According to DMRC, 140,000 people use the feeder buses every day, but only 40,000 of them are passengers of the metro, indicating that the feeder buses are not necessarily used as a means to connect a metro station

respondents were as follows: male 100 (81%) and female 24 (19%). According to DMRC, females normally make up about 25% of total passengers.

and the final destination. With regard to the connectivity between the metro and the feeder buses, according to the beneficiary survey, 17% (21 respondents) of the passengers said "well connected" and 12% (15 respondents) "not well connected" while 71% (88 respondents) do not use the feeder bus[11].

Safety and security of the metro operation

For security of the metro, the Central Industrial Security Force (CISF), a paramilitary force, is deployed at the entrance for frisking passengers and X-ray screening of their luggage. The safety inside the station is centrally monitored at the control room located in each station. The trains are equipped with surveillance cameras to monitor their interior at all times. In major stations, security personnel are deployed at the platforms to prevent accidents when the train arrives. Moreover, in the stations with many users and new stations, screen doors at the platform are being installed. In operational manuals on safety and disaster management, detailed procedures and instructions are spelled out in case of bad weather and coordination with the National Disaster Response Force.

Based on the site visits and interviews, it seems that necessary security measures are in place for the operation of the metro. At the same time, some passengers were seen standing beyond the warning blocks while waiting for the train, and large crowds were formed during the peak hours because of the security check. In a few stations, long queues waiting for the security check were continuing outside the station premises. DMRC has introduced additional metal detectors and X-ray machines in some of the stations and requested the CISF to deploy more personnel to deal with peak hour crowds. Nevertheless, considering that the ridership is expected to increase, it is necessary to address overcrowding and security check during the peak hours. In the beneficiary survey, complaints regarding overcrowding due to security checks and breakdown, slow response and poor performance of the automated fare collection (AFC) gates were heard.

Improved services

For riding the metro, ticketing is done by either a token or a prepaid smart card, and all entry and exit gates are automated. Moreover, there has been a tie-up with the debit card of a local bank named ICICI Bank since 2015, and the smart card can be recharged through Paytm, an e-commerce system. At the time of the ex-post evaluation, the smart card can be used in all lines of Delhi Metro including Airport Express Line and feeder buses as well as Gurgaon Rapid Metro located outside Delhi (but not possible for use in metros of other cities).

[11] If the originating and destination points are within the walking distance from a metro station, there is less need to use the feeder bus. Also, Noida Sector 16, which is one of the beneficiary survey locations, is outside Delhi and does not have feeder buses operated by DMRC. Therefore, the share of respondents who use the feeder buses was low.

There is a 24-hour customer helpline and any complaints and suggestions filed are referred to the concerned officer while they are also uploaded to the customer management system. Each station has a complaint-lodging book. When a complaint is filed, one of the station personnel must address it, and the action taken by the station personnel must be recorded. DMRC conducts a customer satisfaction survey every year on eight parameters such as access, comfort, and quality of service. In a 2014 customer satisfaction survey by Community of Metros (CoMET), an international metro benchmarking forum, which compared 18 metros around the world, DMRC was ranked second.

In the beneficiary survey of the ex-post evaluation, the passengers were asked about services provided by DMRC personnel. Out of the 124 respondents, 95 (77%) said that they found them to be "courteous/helpful." As for the fare structure of the metro, 87% felt "just right[12]" while 65% also felt the frequency of the train was "just right." At the same time, to handle the increasing ridership, some opined that the frequency of trains and the number of coaches should be increased during the peak hours[13]. Other than these, in the customer satisfaction survey of DMRC, the satisfaction with the environment outside the station was low. Specifically, the passengers pointed out issues such as cleanliness outside the station, parking space, access to the final destination from the metro, and sidewalks, all of which require coordination with other civic agencies. As described in the section on "3.4 Impacts," coordination with other civic agencies has been also pointed out from the perspective of improving access for differently-abled people[14].

3.4 Impacts

3.4.1 Intended Impacts

The expected impacts of the Project were "the regional economic development and improvement of the urban environment through alleviation of traffic congestion and reduction of traffic pollution." At the time of the appraisal, specific impacts were not spelled out. Thus, "improvement of urban environment" and "regional economic development" were further broken down as follows:

Improvement of urban environment	Regional economic development
a. Reducing traffic congestion b. Saving travel time c. Reducing road accidents d. Reducing energy consumption e. Reducing air pollution f. Reducing noise pollution	g. Increase in property value along the metro corridor h. Increased business activities along the metro corridor

[12] Because all the respondents are metro users, it is likely that they feel the fare structure is appropriate.
[13] At the time of the ex-post evaluation, trains are operated in four, six or eight coaches depending on the line. For the lines that have a large ridership especially during the peak hours, eight coaches are used.
[14] Apart from these, DMRC is taking initiative on public relations and effective use of public space. It took unique initiatives such as accepting study tours, having exhibition space in the station, and setting up a metro museum in 2008 at Patel Chowk Station.

a. Reducing traffic congestion

According to an estimate of the Central Road Research Institute (CRRI), the Project has reduced traffic volume equivalent to 419,000 cars in FY 2015[15]. However, the number of registered vehicles in Delhi is still on the rise even after the opening of metro and there has not been visible change in easing the traffic. Similarly, in a study on traffic volume conducted by the CRRI on Phase 1 corridors in 2007 and 2009, a significant increase has been observed on the roads parallel to the metro. In the beneficiary survey, the residents were asked about traffic volume around the main intersections nearby comparing before and after the opening of the metro. Thirty-five percent responded that there is "no change" while those answered "slightly increased" and "significantly increased" were 27% each, indicating that nearly 90% of the respondents do not recognize reduction in traffic volume due to the metro[16]. In addition, there are place around the metro station where cycle rickshaws waiting for customers are encroaching to the road triggering traffic congestion.

b. Saving travel time

According to a CRRI estimate, saving on travel time is about 30 minutes per trip. In the beneficiary survey, metro passengers were asked to compare the travel time for the same sector using the metro and other means. Ninety percent of the respondents answered that the travel time was reduced by using the metro.

c. Reducing road accidents

Table 5 shows the number of registered vehicles in Delhi and changes in the number of traffic accidents. The occurrence of traffic accidents per 10,000 vehicles is also calculated based on these data. Compared to 2006 when the operational network of the metro was limited, the occurrence of accidents has decreased to half (from 19 to 10 incidents) after 2010. According to the CRRI's estimate on "number of traffic accidents prevented," calculated based on years of traffic accidents, average vehicular kilometer and traffic volumes reduced by the Project, in recent years about 100 fatal accidents and 800 injury accidents were prevented annually.

[15] CRRI. *Quantification of Benefits for Delhi Metro Phase I* (August 2009).
[16] Other responses include two respondents (8%) "slightly reduced" and one respondent (4%) "significantly reduced."

Table 5: Changes in Number of Registered Vehicles and Traffic Accidents in Delhi

	2006	2010	2012	2014
Registered vehicle (10,000)	523	693	777	883
Traffic accidents	9,699	7,220	6,937	8,623
Occurrence of accidents per 10,000 vehicles	19	10	9	10

Source: Prepared by the External Evaluator based on materials provided by DMRC

d. Reducing energy consumption

Based on the traffic volume reduced by the Project, the CRRI has estimated the amount of energy reduction per annum. The result shows that in 2007, 2011 and 2015, the amount reduced was 24,691 tons, 106,439 tons and 299,000 tons respectively. Comparing the figures from 2007 and 2015, because of the expansion of the metro network, the amount of energy reduced became tenfold in the eight-year period.

e. Reducing air pollution

Because the number of vehicles in Delhi continues to increase, the problem of air pollution has only worsened and there has been no visible improvement. A study was conducted to see how much of air pollution was controlled by the Project[17]. It observed the levels of NO_2, CO, and PM 2.5 from 2004 to 2006 at two locations in the city, namely ITO and Siri Fort. The study found that the Project reduced CO by 34%.

To reduce air pollution from electricity needed for metro operation and save energy, DMRC has installed a regenerative braking system on trains. The system supplies the kinetic energy generated from applying the brakes back to overhead electricity lines and reuse the energy. This initiative was registered as the first Clean Development Mechanism project in the railway sector and 220,591 CER[18] was traded between 2007 and 2012.

f. Reducing noise pollution

It is conceivable that, when the metro becomes operational, the traffic volume along the corridor would decrease, and the noise pollution in the area would also be reduced. According to DMRC's monitoring on the noise level along Line 6, 1.2 to 5.5 decibels of noise was reduced after the metro became operational.

By contrast, according to the study by the Council of Scientific and Industrial Research on

[17] Deepti Goel and Sonam Gupta (2015). *The Effect of Metro Expansion on Air Pollution in Delhi*. Police Research Working Paper 7448.
[18] Certified emission reduction

the noise level of elevated corridor of Phase 1 of the Project, an increase of 1.7 to 1.8 decibels was observed after the metro became operational within the 10-m radius from the corridor.

In the beneficiary survey, two out of the 26 respondents who were residents along the metro corridor said that the noise arising from the congestion near the metro station is of a concern. It indicates that the Project has not necessarily contributed to reducing the noise level depending on the area.

g. Increase in property value along the metro corridor

According to a study on property value along the Phase 1 corridor comparing before the metro construction (before 1996) and after the metro became operational (2001 to 2006) , the value within the 500-m radius from the corridor has increased on annual average by 11.3% (residential) to 18.1% (commercial). The property value has steadily increased after the metro became operational instead of during the construction period. In addition, a real estate website that compared property value between 2005 and 2008 also reported that there was an 18 to 40% increase per annum in north and western Delhi where the metro started operating.

In the beneficiary survey covering the residents along the metro corridor, 70% (18 respondents) said that the property value has increased after the opening of metro and they feel the change is boosted by the metro. The business establishments (6 establishments) along the metro corridor gave similar responses.

h. Increased business activities along the metro corridor

In the beneficiary survey, six business establishments that had been in operation near the metro corridor since the time before the metro opening were interviewed to see changes in business activities. Two respondents each replied that business activities "increased significantly," "increased slightly," and "no change." Four respondents with who felt increase in business activities cited as a reason the increase in the number of customers. A bank and a coaching center (tuition center) that were interviewed felt that more customers come from distant places using the metro than before.

As can been seen so far, with regard to improving the urban environment, it is difficult to specify the degree of impact because there are factors other than the Project particularly in relation to reducing traffic congestion, air pollution and noise level. However, it does not undermine the impact made by the Project. Actually, while traffic congestion in Delhi is not resolved, the impact from saving in travel time using the metro has been considerable as suggested by the CRRI study and the beneficiary survey. Moreover, reducing the number of traffic accidents and energy consumption has a significant effect on not only the urban environment but also on the economy in general. With regard to impact on the local economy, the Project is contributing to revitalization along the metro corridor while DMRC has its own initiative to provide commercial space within the metro station. Furthermore, considering that

many street vendors and new businesses popped up around the metro stations close to residential and office areas, although specific economic impact has not been measured, the Project has contributed to development of the local economy.

3.4.2 Other Impacts

3.4.2.1 Impacts on the Natural Environment

The Project was classified as Category A of the JICA guidelines on environmental and social considerations (April 2002) because it falls under the rail sector and was considered to have sensitive characteristics. During the Project implementation, the contractors conducted the environmental monitoring while DMRC monitored regularly the air and water qualities, noise and vibration after the Project completion. It was decided during the appraisal in 2006 to take necessary measures for reducing the noise, and noise barriers such as soundproof pads, sound insulating walls, and silent generators were arranged. Mitigation measures such as watering the site and frequent cleaning of the streets were implemented because a few areas complained about dust from the construction site.

With regard to the natural environment, the negative impact was considered minimal because the Project site is located in urban areas and most of the planned corridors pass through the existing road. The Project implemented thoroughly the practice of planting 10 trees in place of one that required felling for the construction.

Arrangements for environmental monitoring are in place both during the Project implementation and after its completion. During the implementation, there was a system to accept complaints from local residents, and if there were complaints on such matters as noise, measures were taken to minimize the negative effect.

3.4.2.2 Land Acquisition and Resettlement

At the time of the 2006 appraisal, the size of land acquisition required for the Project was estimated to be 99.05 ha and the number of structures that required resettlement was 986. Land acquisition and resettlement were planned to be completed by April and July 2007, respectively. However, owing to change in the Project scope and the route, the land acquisition ultimately became 204.16 ha and 971 structures were resettled; the process was completed in December 2009. Table 6 shows the comparison of the planned and actual land acquisition and resettlement.

Table 6: Planned and Actual Land Acquisition and Resettlement

	Plan (2006)	Actual
Land acquisition (ha)	99.05	204.16
No. of structures resettled	986	971*

Source: DMRC

*At the time of project completion, the number of structures (households) resettled was 1,364. However, the Delhi High Court subsequently ruled that 393 slum structures in Sarita Vihar were illegal and were not entitled for compensation. Therefore, these households were excluded from the resettlement.

Land acquisition was carried out in line with Land Acquisition Act while resettlement was carried out in line with Relocation and Rehabilitation Policy in Respect of Project Affected Persons of All Categories Due to Implementation of Delhi MRTS Project passed in 2006. DMRC submitted the amount required for resettlement and compensation to the Delhi government, and the processes were carried out by the land acquisition officer of the government. Residential structures in the relocation sites were taken care of by the Delhi Development Authority. For commercial establishments that required relocation along Line 5, DMRC constructed a commercial complex and provided the space for 104 units near Nangloi Station at a cost. The Slum Department of Delhi government took responsibility for relocating illegal settlements.

As was originally planned, the living conditions of slum residents after resettlement were monitored quarterly by an NGO from 2007 to 2008. Subsequently, a follow-up survey was conducted in 2010 noting that there are roads, water supply and basic social infrastructure (a school and a clinic) near the relocation site.

The NGO surveyed the average monthly income at the relocation sites of Savda Ghevra and Holambi Kalan soon after the relocation (2007) and after three years (2010). It was found that, in Savda Ghevra, the income increased from INR 3,600 to 5,270, and INR 4,480 to 6,273 in Holambi Kalan, indicating some improvement in livelihood compared to the time right after the relocation[19]. During the site visit of the ex-post evaluation, the resident representative of Savda Ghevra was interviewed. He stated that, compared to just after the relocation in 2008, the road network connecting to the city center improved but there were not enough bus services. He also said that because of the distance from the city center, it was difficult for the residents to find employment and commute. Particularly, 25% of the resettled residents have since left the relocation site citing the difficulty to commute among other reasons. By contrast, there are

[19] Even if the inflation rate (annual average of 10.9%, the World Bank) is taken into account, it is fair to say that there has been a slight improvement in the income level.

reliable services like water supply and electricity compared to before the relocation.

3.4.2.3 Unintended Positive/Negative Impact

Prevention of HIV/AIDS

A high risk of HIV infection was a concern because many migrant workers who were without families were involved in the construction for the Project. As part of DMRC's corporate social responsibilities, activities for preventing HIV were to be implemented in cooperation with a NGO. Referring to the same initiative taken under Phase 1 of the Project, activities like awareness raising, peer education and distribution of condoms were implemented.

Consideration for Elderly and Differently-Abled

In accordance with the Indian law, the Project constructed stations (elevators, toilet, announcement and tactile path) and trains (space for wheelchair) considering the use by the elderly and differently-abled people. Particularly, the Project strived to implement universal designs with the help of an organization that is an advocate for the physically challenged. At the time of the ex-post evaluation, each metro station is equipped with a wheelchair and elevators that cater for the use of a wheelchair. In the station building, there are wheelchair-accessible toilets and some of the parking lots have designated space for the differently-abled. The first and last coaches of the train have space for a wheelchair and there are priority seats for the elderly and differently-abled. Each station has a tactile path as well.

However, in an interview with Samarthyam, an NGO for the differently-abled, the following issues were pointed out for further improvement.

- Install a tactile path leading to the ticket vending machines.
- Remove the security booth placed on top of the tactile path in the station.
- For people with visual impairment, install audio announcement in vending machines.
- Improve information access (display of locations of elevators in the station map on the website)
- Introduce non-step buses in some of the feeder buses.
- Improve the access around the metro stations. Work with other civic agencies to resolve the issue such as paving the sidewalks and distance to pedestrian crossings.

Safe Mobility for Women

Although the opportunity for women to go out safely was not an impact clearly considered at the time of the appraisal, the metro has brought about a means of transport in which women can travel safer than before. It may have also improved the local security around the metro station as a secondary impact. To verify the hypothesis, 150 metro passengers and residents (116

men and 34 women) were asked about changes in the local security situation and the safe mobility for women. The results showed that 85% of the respondents felt the security around the metro station improved because of the opening of the metro.

Furthermore, the respondents were asked about changes in timing of women going out after the opening of the metro (male respondents were asked to report the cases of female family members). It was found that women tend to go out more in the evening and late hours than before. As can be seen, the Project has contributed to providing more opportunity for women to go out safely.

<Column: The metro helps women's empowerment>

In India, public space like bus and train stations is where women are likely to face harassment. The metro is no exception. However, the Delhi Metro has women-only coaches in all trains and is equipped with surveillance cameras in the trains and stations. When inquired about women-only coaches in the beneficiary survey, 86% of the passengers (107 respondents) consider them "helpful." Nine percent (11 respondents) felt "not very helpful" and 2% (2 respondents) said "not helpful at all." The remaining 3% (4 respondents) who did not know the availability of women-only coach were men. Moreover, female security personnel are deployed at the stations and trained CISF female personnel in plainclothes are on patrol to keep the train travel safe. In addition to the women-only coach, because of the opening of the metro stations, it can be said the women have better opportunity to go out with peace of mind. For instance, because metro stations are operational until late at night, the areas around the station where it used to be dark have become better lit and it is now possible for a woman to walk alone. It is supported by the results of the beneficiary survey that shows improved local security and increased frequency of women going out in the evening and night. Furthermore, in interviews with female passengers, some noted that they depended on male family members and private vehicles earlier because they felt uncomfortable going on auto rickshaw, but now they are able to go out alone.

The Project has largely achieved its objectives. Therefore, the effectiveness and impact of the Project are high.

3.5 Sustainability (Rating: ③)

3.5.1 Institutional Aspects of Operation and Maintenance

DMRC is the executing and O&M agency of the Project. DMRC was established in May 1995 under the Indian Companies Act of 1956 to implement the Delhi Mass Rapid Transit System Project with equal capital from the governments of India and the NCTD. DMRC was

given authority to implement the Project under the Metro Railways (Construction of Works) Act of 1978 and to operate and maintain the system under the Metro Railways (O&M) Act of 2002.

At the time of the ex-post evaluation, DMRC has 8,628 employees. Out of them, 2,173 were recruited for the operation of Phase 3. Each station has about 10 personnel from DMRC including a station manager (in charge of 2 to 3 stations), 2 to 4 station controllers and several customer care agents depending on the footfall at the station. In addition, housekeeping and security personnel are provided by external agencies. In each depot, about 200 personnel are working on maintenance of coaches.

At the time of the ex-post evaluation, problems such as shortage of staff were not seen, and the roles and responsibilities of O&M staff are clearly stated in operation manuals and rules. Various initiatives are taken to maintain and boost the personnel's morale. For instance, personnel are awarded for their outstanding performance while staff housing and loans are provided and there are regular meetings with human resource officers. Under the corporate vision of "commuting experience in Delhi Metro to be customer's delight," DMRC conducts regular seminars and training for behavioral change of staff aiming to provide services that exceed the expectations of the customers. Therefore, institutional arrangements for O&M are established.

In Delhi, there is a Unified Traffic and Transportation Infrastructure (Planning & Engineering) Center (UTTIPEC) which is mandated to plan and coordinate with various transport-related member agencies. Apart from DMRC, DTC, municipalities, and the Public Works Department are UTTIPEC members. Through UTTIPEC, any matters that require coordination with other mode of transport are discussed.

3.5.2 Technical Aspects of Operation and Maintenance

From the time of the appraisal in 2006, DMRC has a number of engineers who have come from the Indian Railways, and thus there were no issues with regard to the basic technical standards. Moreover, because DMRC has experience of O&M of the lines in Phase 1 that are fully operational, it was considered that there is no issue with its capacity. O&M manuals are prepared by system suppliers and used by the DMRC personnel, and updated when necessary.

DMRC recognizes that continuous upgrading of technical skills is required for improving O&M-related skills and strives for that purpose. It has its own ISO 9001-2008 certified training institute attached to the Shastri Park Depot and staff training takes place at the institute. The institute, established in 2002, is the first metro training institute in India and equipped with demonstration facilities such as train simulator and signaling system as well as hostel facility. Those taking up the job of train drivers are required to undergo 30 weeks of training and practice 5 hours at the simulator for each type of rolling stock[20].

[20] DMRC currently operates three types of rolling stock.

Table 7 shows the training courses planned and conducted at the institute in the last three years. The institute also offers courses for foreign trainees. There have been trainees from Bangladesh, Nepal and Indonesia. For other metros in the country, training courses on management, electrical and telecommunication and rolling stock maintenance have been offered. Annually, about 8,000 people take courses at the institute.

Table 7: Training Courses Conducted at the Institute

Unit: Courses

	2013	2014	2015
Induction training	33	34	37
Refresher training	98	71	84
Customized training	3	6	6

Source: DMRC

Taking advantage of the experience of implementing and operating Delhi Metro, DMRC now uses its knowledge and technical skills to provide services such as consulting and implementation of metros in other cities. As can be seen, DMRC not only maintains and improves the technical skills of its own employees but is technically contributing to other metro projects. Thus, it is fair to say that its technical standards are high.

3.5.3 Financial Aspects of Operation and Maintenance

Given that the corridors under Phase 1 were commissioned from 2004 onwards, DMRC was financially sound at the time of the appraisal in 2006. In FY 2008, the net profit marked a surplus, but it has been in deficit since 2009. Apart from the fare box revenue, the sources of O&M finance for DMRC includes earnings from lease operations (advertisement and property development) and feeder buses.

Table 8: Revenue and Net Profit for the Last Five Years

Unit: INR million

	2010	**2011**	**2012**	**2013**	**2014**
Total revenue	16,079	22,478	26,875	31,978	35,623
Fare box revenue	7,466	10,163	12,230	13,648	15,057
Other revenue	8,614	12,315	14,645	18,329	20,565
Operating profit	7,505	9,334	10,278	10,621	12,399
Net profit (after tax)	(4,139)	(1,851)	(909)	(998)	(1,048)

Source: DMRC Annual Reports

As seen in the above financial indicators, the total revenue has been steadily increasing. The debt equity ratio has also improved from 1.43 in 2006 to 1.15 in 2014. Operating profit has been in good condition since the commissioning of the metro and while net profit is in deficit, from the point of view of cash flow, it would not pose a financial problem for DMRC to perform O&M.

The reasons for net profit being in deficit include lack of fare revision since 2009 and the increasing operational cost. The fare structure is to be revised in accordance with the Metro Railways (O&M) Act by the Fare Fixation Committee set up by the Ministry of Urban Development from time to time considering the inflation and fares of other transport modes. During the ex-post evaluation, the Fourth Fare Fixation Committee was constituted and fare revision may take place as early as within 2016 based on the recommendations of the committee. It has been more than 10 years since the opening of the Phase 1 corridor. Considering the necessity for maintenance of various systems and the increasing material costs, fare revision is essential.

To increase the revenue from fare box, DMRC has been trying to strengthen the revenue sources by increasing the number of coaches and taking up consulting services for metro projects in other cities. Since 2010, the second largest share of revenue after fare box is the income from external projects (32% share in FY 2014); however, income revenue from the consulting services and external projects cannot be expected in the long term. In recent years, DMRC has started new initiatives such as station naming rights and train wrapping[21]. However, some of such initiatives can be done only outside Delhi. Therefore, expanding these initiatives and regular revision of metro fare will be necessary in the future.

3.5.4 Current Status of Operation and Maintenance

In the Project, maintenance activities for rolling stock, tracks, buildings, telecommunication systems, AFC gates, and electrical facilities are carried out. Eight depots are in operation to maintain the coaches for corridors that are operational at the time of the ex-post evaluation (four of the eight were constructed by the Project). Regular maintenance is conducted based on the number of kilometers run by the train apart from daily inspection which is conducted prior to services according to the check sheet.

Depending on the kind of maintenance services to be done, different activities are carried out at various points in the depot. Rolling stocks are provided with a two-year warranty period. In the site survey, it appeared that the depots are maintained in order and clean. As can be seen, regular maintenance activities are carried out and a proper environment is established for the maintenance. As in the case of rolling stock, DMRC recommends domestic production of spare parts. Production centers have been established by private firms in the country, and procuring

[21] To wrap trains with advertisement films.

spare parts is not difficult. Moreover, having 90% of the spare parts produced domestically has contributed to cutting down the cost. The Project has been procuring the spare parts that will be required for 4 to 5 years after the Project completion as part of the Project cost, and transfers them to the O&M department, thereby ensuring that there will be no shortage of spare parts.

Regular inspection is conducted for station buildings as well. Monthly inspection is done according to a prescribed four-page checklist. The station manager checks the condition of equipment and manuals and reports it to the headquarters. Considering that Delhi tends to be dusty, the stations visited during the site inspection were comparatively clean. However, as was pointed out in the beneficiary survey, AFC gates seemed to have frequent breakdown. The problems with AFC gates appear to be triggered by rush use by passengers in addition to malfunction of software.

No major problems have been observed in the institutional, technical and financial aspects of the operation and maintenance system. Therefore, the sustainability of the Project effects is high.

4. Conclusion, Lessons Learned and Recommendations

4.1 Conclusion

The Project aimed to reduce traffic congestion and pollution by constructing a mass rapid transport system in the NCTD that faced problems of economic loss and air pollution due to traffic congestion caused by rapid economic growth and urbanization since the 1990s. From the time of the appraisal to the ex-post evaluation, the urban transport sector continues to occupy an important position in development plans of the governments of India and the NCTD. The development need for a rapid transport system was seen at the times of both the ex-post evaluation and the appraisal. The Project is in line with Japan's ODA policy, and the relevance of the Project is high. Both the Project cost and Project period exceeded the plan. Therefore, the Project's efficiency is fair. The addition to the Project's scope after its commencement was found appropriate. Most of the operational and effect indicators set at the time of the appraisal have achieved their targets. With regard to impact on such aspects as regional economic development and improving the urban environment, the Project made a certain degree of contribution. Thus, the effectiveness and impact of the Project are determined to be high. DMRC has the institutional structure to operate and maintain the Project as well as necessary technical skills. With regard to the financial status of DMRC, continuous efforts are required to improve it, but no serious issues are found. At the time of the ex-post evaluation, O&M are done properly and the sustainability of the Project is high.

In light of the above, the Project is evaluated to be highly satisfactory.

4.2 Recommendations

4.2.1 Recommendations to the Executing Agency

Fare revision

Since 2009, there has been no fare revision of Delhi Metro. The fare revision is decided by the Fare Fixation Committee constituted by the Ministry of Urban Development when deemed necessary in accordance with the Metro Railways (O&M) Act. As of June 2016, based on the request from DMRC in the past few years, the Fourth Fare Fixation Committee has been constituted and fare revision is being considered. With due regards to inflation and the increase in operational costs, regular fare revision is required in the future as well. To implement regular fare revision, it is desired for DMRC to approach the Government of India.

Further improvement for improving the access for the elderly and the differently-abled

The Project has incorporated the opinions on universal design by the associations advocating for the differently-abled from the planning stage. As a result, trains and station buildings that have given due consideration to the elderly and the differently-abled are highly appreciated. At the same time, there are areas that need improvement such as better information access for the differently-abled, putting a tactile path to the ticket vending machine, installing audio for the vending machine, and instructing DMRC and security personnel to avoid putting things on the tactile path. To improve access for users with diverse needs, further effort is desired through regular discussion with advocacy organizations and taking actions.

Coordination with civic and other transport agencies

As was pointed out by the beneficiary survey conducted during the ex-post evaluation and by the customer satisfaction survey of DMRC, improving access around the metro station is an issue. The issues hampering access of certain users include unpaved sidewalks, road congestion triggered by cycle rickshaws waiting for customers outside the station, and lack of pedestrian crossing on the road with a median. The jurisdiction of space outside the metro stations lies not with DMRC but with other agencies such as the Public Works Department and Municipal Corporation of Delhi. However, DMRC is desired to strive to improve the environment outside the metro stations for better access for their customers through discussions with other agencies. For better access for public transport, it is desirable to continue the coordination with other urban transport agencies such as DTC on matters including the enhancement of feeder bus services.

4.2.2 Recommendations to JICA

None.

4.3 Lessons Learned

Strengthening technical expertise of internal human resources beyond project implementation

DMRC has been trying to strengthen the technical expertise of its human resources from the implementation of Phase 1 with a view to implementing subsequent phases. Specifically, it was able to reduce the dependence on external experts in Phase 2 by deploying its personnel in consulting services and allowing them to have relevant technical experience from the beginning. Moreover, DMRC is passing on the technical expertise built up from the project implementation in its own personnel to new metros through its training institute. By taking up external projects to implement other metro projects, DMRC is contributing to disseminating its technology to other metros in and out of India as well. Systematic and effective use of technical expertise accumulated in the executing agency is a good practice. It would be desirable for new metro projects in other countries and projects employing new technology to consider taking up similar initiatives with a view to expanding their business in the future.

Comparison of the Original and Actual Scope of the Project

Item	Plan	Actual
1. Project Outputs	Civil works 82.69 km Electrical, signaling, and telecommunication system Procurement of rolling stocks: 672 cars Construction of depots: 4 *Based on 2010 appraisal	82.80 km As planned 734 cars As planned
2. Project Period	March 2006 – November 2010 (57 months)	March 2006 – August 2011 (65 months)
3. Project Cost		
Amount Paid in Foreign Currency	80,567 million yen	95,578 million yen
Amount Paid in Local Currency	258,216 million yen (INR 97,704 million)	284,288 million yen (INR 141,437 million)
Total	338,782 million yen	379,866 million yen
Japanese ODA Loan Portion	162,955 million yen	207,438 million yen
Exchange Rate	INR 1 = 2.49 yen (As of July 2005, original scope), 2.85 yen (As of October 2007, additional scope) *Based on 2008 appraisal	INR 1 = 2.01 yen (Average between March 2006 and March 2015)

Main Contractors (above 1 billion yen)

- Larsen & Toubro Ltd. (India)
- Dywidag-Systems International GmbH (Germany)/Ircon International Ltd. (India)/Larsen & Toubro Ltd. (India)/ Shimizu Corporation (Japan) Samsung Corporation (South Korea)
- Soma Enterprise Limited (India)/Continental Engineering Corporation (Taiwan)
- Ircon International Ltd. (India)
- Alstom Transport SA (France)/Alstom India Ltd. (India)/Sumitomo Corporation (Japan)
- ABB India Limited (India)
- Patil Vossloh Rail System Pvt. Ltd. (India)
- VAE GmbH (Austria)
- Iljin Electric Company Ltd. Seoul (South Korea)
- Kalindee Rail Nirman (Engineers) Limited (India)
- Bombardier Transportation GmbH (Germany)/Bombardier Transportation India Ltd. (India)
- Kone Elevator India Private Limited (India)
- Senbo Engineering Ltd. (India)
- Suzhou Jiangnan Jiajie Elevator Group Company Ltd. (China)/Johnson Lifts Pvt. Ltd. (India)
- Thales Transportation Systems SA (France)
- Nippon Steel Corporation (Japan)/Mitsui & Co. (Japan)
- ITD Cem (India) Italian-Thai Development Public Company Limited (Thailand)
- Fibocm India Limited (India)/Ramco Systems Limited (India)
- Siemens AG Transportation Systems TS RA (Germany)/Siemens Ltd. (India)
- BEML Limited (India)/Mitsubishi Electric (Japan)/Mitsubishi Corporation (Japan)/Rotem Company (South Korea)
- Bombardier Transportation India Ltd. (India)/Bombardier Transportation Sweden AB (Sweden)
- Thales Transportation Systems SA (France)/Thales Portugal SA (Portugal)
- Larsen & Toubro Ltd. (India)/Furrer+Fray AG Ltd. (Switzerland)
- Kalindee Rail Nirman (Engineers) Limited (India)/Samsung SDS Co. Ltd. (South Korea)
- Samsung C&T India Pvt. Ltd. (India)/ Samsung C&T Corporation (South Korea)
- Blue Star Ltd. (India)
- Indu Projects Ltd. (India)/Laing O'Rourke PLC (U.K.)
- ETA Engineering Pvt Ltd. (India)/ Emirates Trading Agency (U.A.E)

Attachment 1: Metro Network of the Project

Outline of the Beneficiary Survey

As a supplementary means to grasp the effect of the Project, questionnaire surveys were conducted targeting the following people who are presumable beneficiaries of the Project: a) metro passengers, b) residents along the metro corridor, and c) business establishments along the metro corridor.

For the survey on metro passengers, a minimum sample size of 100 (valid responses) was taken with the standard error of 10% and the confidence interval of 95%[22]. The survey asked 124 passengers about mainly the convenience of the metro, satisfaction on its services, and safe mobility for women (including male respondents).

For residents along the metro corridor, 25 households were interviewed on the status of noise and vibration during the metro construction, changes in property value along the corridor, the status of local development after the opening of the metro, and changes in traffic congestion.

Six business establishments were interviewed along the metro corridor on changes in business activities and clientele after the opening of the metro.

Survey Locations and Sampling Methods

It would be prudent to include in the survey targets the corridors constructed under Phase 1 and 2 of the Project because the effect of the Project extends to the entire metro network. In addition to the extension of the Phase 1 corridor, namely Line 1 to 4, the new corridors Line 5 and 6 were commissioned under Phase 2. The survey on metro passengers was conducted at two locations because passengers' characteristics vary depending on the corridor and the locality where the station is located. The survey locations were randomly selected from the list of stations opened under Phase 2. Accordingly, Noida Sector 16 Station of Line 4 and Kailash Colony Station of Line 6 were selected. The survey was conducted during the peak hours on working days, off-peak hours on working days, and on a holiday (Sunday) as it is assumed that the characteristics of passengers vary depending on the time of the day. Three enumerators were assigned and the surveys were carried out on March 14–15 at Noida Sector 16 Station, March 16–17 at Kailash Colony Station, and March 20 at both stations. For sampling, the enumerators were positioned at the exit gate and selected the passengers who came through the gate every five minutes.

With regard to residents and business establishments along the metro corridors, basically the same two locations were used. However, because many residents declined to take part in the survey, two additional locations (four locations in total) were selected. The additional locations were Punjabi Bagh Station and New Ashok Nagar Station.

Regarding residents, houses and apartment buildings within the 500-m radius from the selected station were sampled, beginning with those who were closest to the station. In the survey plan, every third house was to be sampled; and in the case of apartment buildings, five flats were sampled by dividing the total number of the flats.

With respect to business establishments, six were interviewed to substantiate the impact of the Project as a reference, particularly the changes in business activities caused by the Project. Interviews were sought from those closest to the metro station: three at Noida Sector 16 Station, two at Kailash Colony Station, and one at New Ashok Nagar Station. To be interviewed, establishments needed to have been operating at the same location since the time prior to the Project implementation. The business types of the six establishments interviewed are as follows: courier service, bank, coaching center (tuition center), restaurant, automobile parts shop, and construction material shop.

Limitations of the Beneficiary Survey

The characteristics of metro passengers differ depending on the locality and the location of the station in Delhi. The beneficiary survey does not necessary reflect the whole picture of the

[22] This survey was not meant to make judgement based on rejecting null hypothesis by hypothesis testing.

passengers because only a limited number of samples were taken. In addition, best effort was made to sample the respondents in such a way as to minimize selection bias. However, it was impossible to avoid self-selection bias because some of the passengers declined to take part in the survey as they were in a hurry particularly during the rush hours (out of the 286 passengers approached for the survey, 124 took part in the survey). Thus, off-peak hours on weekdays had the highest number of responses.

Similarly, sampling methods were established for surveying residents and business establishments. Nevertheless, some residents declined to take part in the survey, and some security guards of the residential area prohibited the enumerator from entering the area. Therefore, sampling was done wherever possible starting with the buildings nearest to the metro station. It was made sure that the respondents had been living in the survey location since the time of the Project implementation.

Results

1. Metro passengers: The following are the profile and responses of the respondents.

<Profile of respondents>

Number of respondents by survey location

Location	No.	%
Kailash Colony	60	48%
Noida Sector 16	64	52%
Total	124	100%

Survey timing

Timing	No.	%
Peak hours on working days	44	35%
Off-peak hours on working days	60	48%
Holiday	20	16%
Total	124	100%

Gender

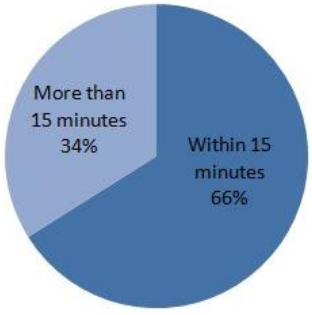
Gender	No.	%
Male	100	81%
Female	24	19%
Total	124	100%

Age

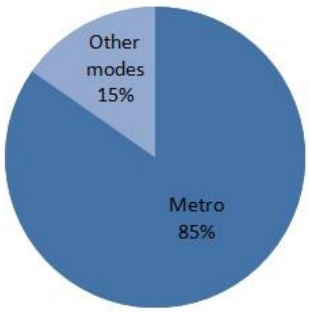
Age	No.	%
20s	71	57%
30s	34	27%
40s	13	10%
50s	3	2%
60 and above	3	2%
Total	124	100%

<Access to public transport>

Walking time from home to the nearest metro station

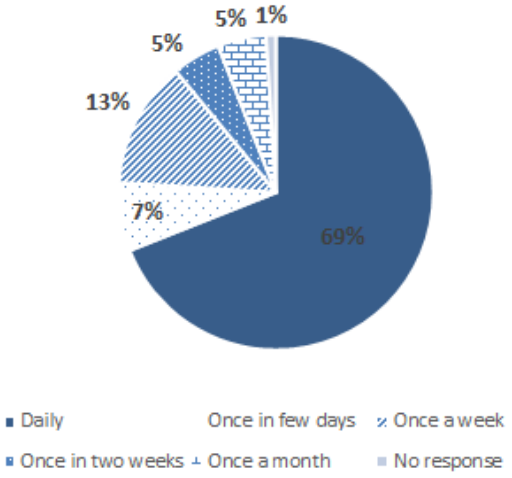


Main means of transport



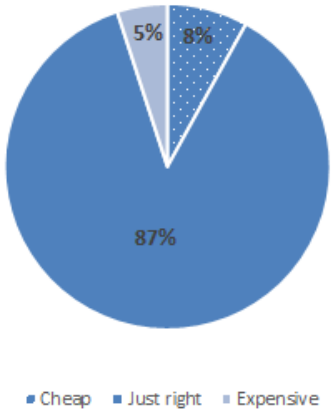
Attachment 2: Summary of the Beneficiary Survey

Frequency of using the metro

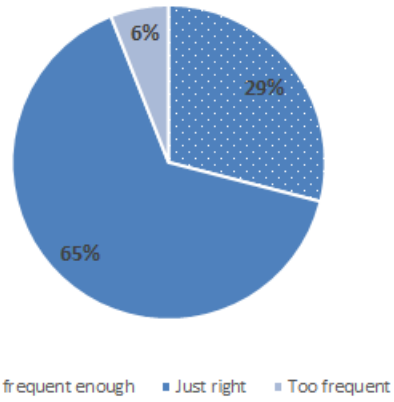


<Satisfaction on the metro service>

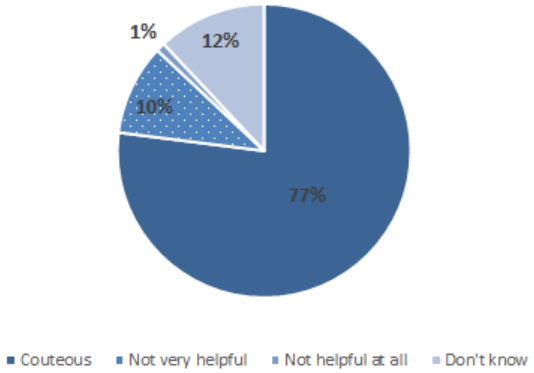
Fare structure



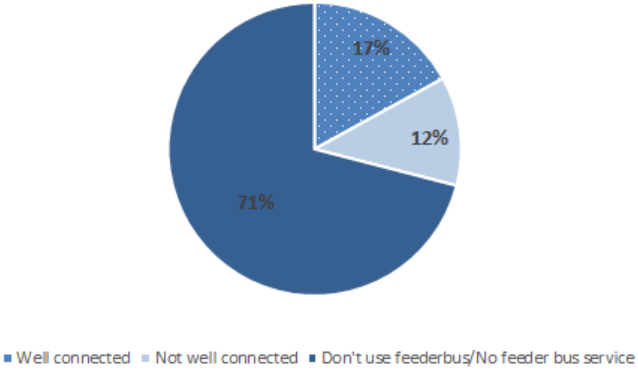
Frequency of train



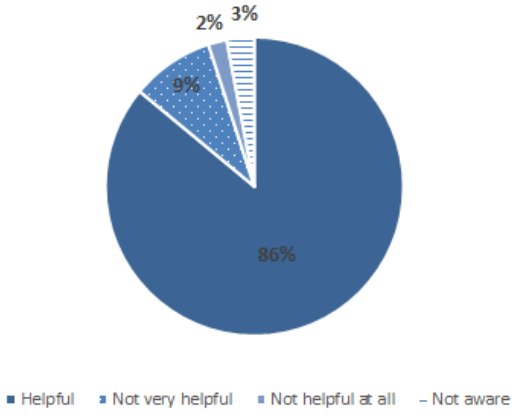
Service provided by station staff



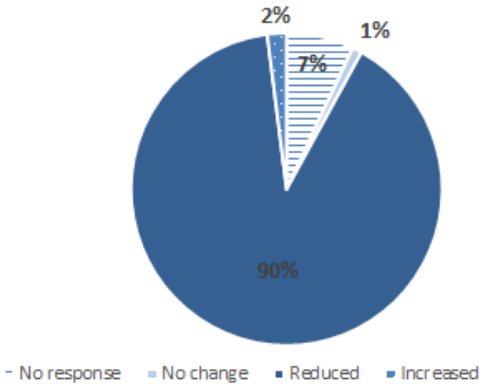
Connectivity with feeder bus



Women-only coach



Changes in transit time



<Safe mobility for women>

Gender wise responses are shown below. They include those from the passengers and residents as the same questions were asked to both groups (150 respondents in total). Male respondents were asked about the situation of female family members.

Change in women's outing after opening of the metro

	Female	%	Male	%	Total	%
Increased	34	100%	109	94%	143	95%
Reduced	0	0%	2	2%	2	1%
No change	0	0%	5	4%	5	3%
Total	34	100%	116	100%	150	100%

Change in the security situation around the metro station

	Female	%	Male	%	Total	%
Improved	30	88%	97	84%	127	85%
No change	4	12%	18	16%	22	14%
No response	0	0%	1	1%	1	1%
Total	34	100%	116	100%	150	100%

Changing time of women going out after opening of the metro

	Female	%	Male	%	Total	%
More outing in evening/night	30	88%	92	79%	122	81%
More outing in daytime	2	6%	16	14%	18	12%
No change	1	3%	1	1%	2	1%
More outing in daytime and evening/night	1	3%	7	6%	8	5%
Total	34	100%	116	100%	150	100%

2. Residents along the metro corridor: 26 people were interviewed at four locations.

<Profile of respondents>

Number of respondents in survey locations

	Person	%
Noida Sector 16	11	42%
New Ashok Nagar	8	31%
Punjabi Bagh	3	12%
Kailash Colony	4	15%
Total	26	100%

Gender

	Person	%
Male	16	62%
Female	10	38%
Total	26	100%

Age

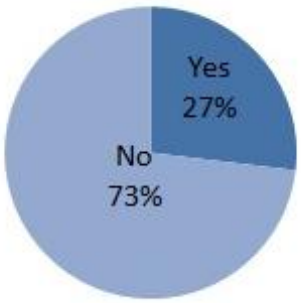
	Person	%
20s	5	19%
30s	4	15%
40s	4	15%
50s	5	19%
60 or above	8	31%
Total	26	100%

Frequency of using the metro

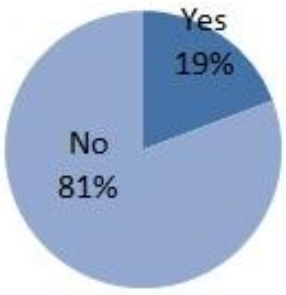
	Person	%
Daily	4	15%
Once every few days	4	15%
Once a week	5	19%
Once every two weeks	2	8%
Once a month	6	23%
Rarely	5	19%
Total	26	100%

<Noise and vibration during the Project implementation>

Whether the noise and vibration have bothered the respondent



Whether there were other concerns during the construction[23]

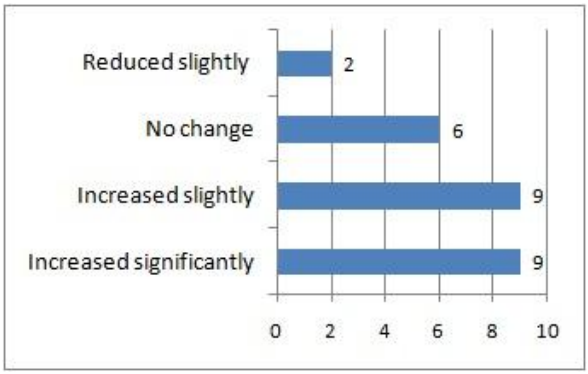


[23] For those answered "Yes" to the question, the specific concerns mentioned were traffic congestion around the construction sites.

<Situation of property price and development along the corridor>

Changes in property price and rent before and after the metro

Unit: Person



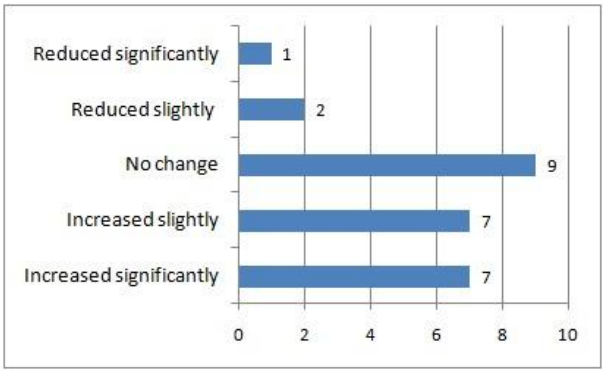
(If the price increased) whether the price rise was triggered by the opening of the metro

	Person	%
Yes	18	100%
No	0	0%
Total	18	100%

<Situation along the corridor after the opening of the metro>

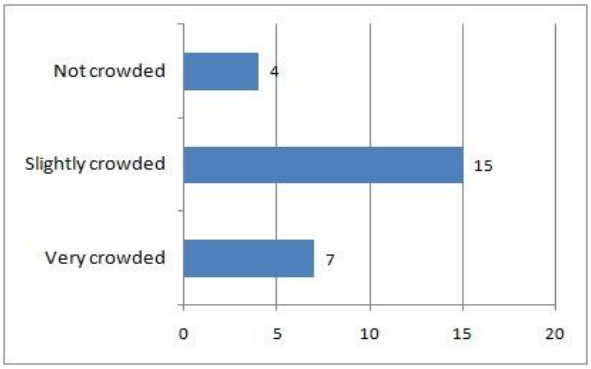
Traffic volume at the intersection

Unit: Person



Congestion around the metro station

Unit: Person



3. As for the survey of business establishments, interviews were conducted to understand the changes in business turnover before and after the Project because the sample size was limited. Below are a few excerpts from the interviews.

- After the opening of the metro, bank, coaching center and IT businesses increased in the area. (Noida Sector 16)
- The metro made commuting more convenient for the employees and reduced their commuting time. (Noida Sector 16)
- More customers from distant places come using the metro who otherwise did not come before. (Bank and coaching center)
- Our clientele is mostly upper-class to begin with. We have seen little change since the opening of the metro because wealthy people do not use the metro often. (Restaurant)
- More people come and go after the opening of the metro. At the same time, the number of criminal incidents seems to have increased. (Noida Sector 16)
- The congestion around the metro station particularly during the rush hours is really bad.