2022 Simplified Ex-Post Evaluation Report of Japanese ODA Loan Project

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Duration of Study: December 2022-March 2024
Duration of the Field Study: 14-28 February, 2023

Country Name	Madhya Pradesh Transmission System Modernisation Project
India	

Location of the Project site
(Source: prepared by the external evaluator)

Jabalpur Substation constructed under the Project
(Source: photo by the external evaluator)

I. Project Outline

Background	In the Indian power sector, central and state government agencies are responsible for policy formulation and regulatory oversight, while central, state, and private power utilities are responsible for power generation, transmission, and distribution operations. The government has distanced itself from regulatory supervision, with Regulation Commission at the central level overseeing inter-state matters and each State Regulatory Commission overseeing intra-state matters. For power transmission, the national high-capacity, high-voltage transmission networks are developed, owned, and operated by the Central Transmission Utility, while the transmission networks within each state (400 kV, 220 kV, and 132 kV) are constructed, owned, and operated by the state transmission companies. At the time of planning (2011), in the state of Madhya Pradesh (hereafter referred to as "MP"; population 72.6 million in 2011), where robust economic development was expected, two new thermal power plants were scheduled to come into operation during 2012 to attend the expected increase in urban and industrial electricity demand and to compensate for the electricity supply shortfall were foreseen.[1] The transmission system of MP needed to be strengthened, and the *11th Five Year Transmission Plan* (April 2007 - March 2012) of MP planned an investment of Rs 377 billion in strengthening transmission and substation facilities. Against this background, a loan agreement for the "Madhya Pradesh Transmission System Modernisation Project" (hereinafter referred to as "the Project") was signed in June 2011.			
Objectives of the Project	To establish a stable transmission system, reduce transmission losses, and ensure a stable supply of electricity in the state by modernizing the transmission system throughout the MP State, thereby contributing to the economic development of the state and the western region of India.			
Contents of the Project	1. Project sites: throughout the state of MP 2. Project scope (actual) Construction of transmission lines: 220 kV 341.65 km, 132 kV 1,801.58 km Construction of new substations: eight 220/132 kV substations and 26 132/33 kV substations Strengthening of substations: three 400 kV/220kV substations, 14 220/132 kV substations, 84 132/33 kV substations			
Implementation Schedule	E/N Date	June 6, 2011	Disbursement Date	September 25, 2018
	L/A Date	June 16, 2011	Completion Date	September 2021
Project Cost	E/N Grant Limit / G/A Grant Limit: 18,475 million yen		Actual Grant Amount: 12,465 million yen	
Executing Agency	Madhya Pradesh Power Transmission Company, Ltd. (MPPTCL)			
Conditions	Interest rate 0.5%, repayment period 20 years (including 6 years grace period), untied.			
Borrower	President of India			
Contracted Agencies	Main Contractors: Bharat Heavy Electricals Ltd. (India), B.S. Ltd. (India), Larsen & Toubro Ltd. (India), Unitech Power Transmission Ltd. (India), Shreem Electric Ltd. (India) (the above are contracts worth more than 1 billion yen). Main Consultant: none Procurement Agent: none			

[1] These power plants were put into operation in 2013 and 2014.

II. Result of the Evaluation

<Summary>

The Project was implemented to establish a stable transmission system, reduce transmission losses, and ensure stable supply of electricity in the state by modernizing transmission system throughout the MP State, thereby contributing to the economic development of the state and the western region of India. The objectives of the Project are highly consistent with *India's National Development Policy* and the needs of the power sector in MP State at the time of the ex-ante evaluation. The Project was consistent with Japan's ODA policy. Furthermore, the Project, the Subsequent ODA Loan Project, and the Asian Development Bank (ADB) Project were all implemented in accordance with the *Master Plan of the MP State Electricity Transmission Company Limited* (MPPTCL), showing consistency and synergy among the projects. Therefore, the relevance and coherence of the Project are high. All operation and effect indicators established for the Project have achieved their targets, and the Project is considered to have contributed to them. The transmission system reinforcement by the Project is considered to have increased the stability of transmission through increased redundancy, and the construction of substations near the demand area is considered to have contributed to the improvement of the voltage profile at the customer end and reduction of power outages. Therefore, the objectives of the Project were achieved and its effectiveness and impact are high. The outputs were generally realized as planned. Although the project cost was within the plan, the project period exceeded the plan, and thus the efficiency of the Project is moderately low. The facilities and equipment of the Project are operated and maintained appropriately, and there are no sustainability-related issues in terms of policy/system, institution/organization, technology, or finance. Therefore, the sustainability of the Project is high. Based on the above, the Project is evaluated as highly satisfactory.

Overall Rating[2]	A	Relevance & Coherence	③[3]	Effectiveness & Impacts	③	Efficiency	②	Sustainability	③

<Special Perspectives Considered in the Ex-Post Evaluation／Constraints of the Ex-post Evaluation> (None in particular)

1 Relevance/Coherence

<Relevance>

(1) Consistency with the Development Policy of India at the time of Ex-Ante Evaluation

India's *11th Five Year Plan* (April 2007-March 2012) aimed to achieve an average annual GDP growth rate of 8-9% and more than 10% by the end of its planning period. To support such rapid economic growth, maintaining a stable electricity supply was considered one of the biggest challenges to be overcome, and the plan included the development of 78,600 MW of new power stations, strengthening of inter-regional transmission lines, and promotion of rural electrification.

In 1998, the state government constituted the Madhya Pradesh Electricity Regulatory Commission (MPERC), a statutory independent regulatory authority under the *Electricity Regulatory Commission Act of 1998*. Later, in July 2002, the vertically integrated MP State Electricity Board (MPSEB) was unbundled into five independent corporations with MPSEB as the holding company in accordance with the *Madhya Pradesh Reform Act*. In 2003, the *Electricity Act 2003* was enacted in the country to reform the sector, promote investment through the introduction of competition, protect consumer interests, and ensure the supply of electricity to all citizens.

From the above, there is a high degree of consistency between the Project, which aims to ensure a stable supply of electricity through the construction of transmission facilities in the MP State with the MPPTCL as the executing agency, and India's development policy at the time of the ex-ante evaluation.

(2) Consistency with the Development Needs of India at the time of Ex-Ante Evaluation

In the MP State, electricity demand increased from 42.9 GWh in 2009 to 58.1 GWh in 2014 due to robust economic development, and the electricity shortage rate was expected to reach 25% in 2014. To cope with this, two new thermal power plants were scheduled to come into operation in the State during 2012, which necessitated strengthened transmission facilities. The *11th Five-Year Transmission Plan of MP State* (April 2007-March 2012) planned an investment of Rs 377 billion in the construction of 6,531 km of transmission lines and 63 new substations with a capacity of 11,035 MVA, of which the Project was a part.

From the above, there is a high degree of consistency between the Project and the development needs at the time of ex-ante evaluation.

<Coherence>

(1) Consistency with Japan's ODA Policy at the Time of Ex-Ante Evaluation

In response to the priority objective of the *Country Assistance Program for India* (May 2006), "Promoting Economic Growth," JICA identified "Supporting Sustainable Economic Growth through the Development of Economic Infrastructure" as one of the priority areas for assistance. The stable supply of energy is one of the development issues in the above areas, and the Project is consistent with Japan's development cooperation policy and JICA's development cooperation policy at the time of ex-ante evaluation.

(2) Internal Coherence

The Project's subsequent ODA Loan project, the "Madhya Pradesh Transmission System Strengthening Project" (2015-), was planned in accordance with the Master Plan of the MPPTCL. The facilities of both, the Project and the Subsequent ODA Loan Project, which were implemented according to the same master plan, work in tandem as part of the transmission system. Concrete cases of direct linkage of facilities and equipment of the two projects were identified, such as the installation of transformers under the subsequent project in the substation constructed under the Project. Therefore, synergies between the Project and the subsequent ODA Loan Project have been observed.

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

[3] ④ : Very High ③: High, ②: Moderately low, ①: Low

(3) External Coherence

Since 2007, ADB has implemented three loan projects with MPPTCL. Both the Project and these three projects were planned in a consistent manner by MPPTCL as part of the transmission system. The facilities under these projects function in conjunction with each other. There were some cases where substations and transmission lines constructed under the Project were connected to substations constructed under the ADB projects. Therefore, synergies were observed between the Project and a series of ADB projects.

<Evaluation Result>

In light of the above, the relevance and coherence of the Project are high[4].

2 Effectiveness/Impacts[5]

<Effectiveness>

(1) Positioning of the facilities developed under the Project in the overall transmission system of the MP State

The Project has constructed 2,143 km of new transmission lines. This corresponds to 5.4% of the total transmission line length of 39,582 km in the transmission system in 2020. In the project, 34 new substations were constructed, and new transformers were installed at 18 substations. A total of 2,454 MVA of transformer capacity was added by the Project in these 52 substations. These substations are directly connected to the distribution network with a 33 kV busbar that connects directly to the distribution network operated by the Distribution Companies.[6] This corresponds to 13.4% of the total number of 396 substations in the transmission system in 2020, or 4.1% of the total transformer capacity of 59,705 MVA.

(2) Utilization of the substations of the Project

The average maximum load factor (average daily maximum load in MVA divided by transformer capacity in MVA) of the 52 substations constructed or increased in substation capacity as a result of the Project in 2021 ranged from 24% to 80% (average value 43%). The annual maximum load factor (annual maximum load divided by substation capacity) was less than 89%. According to MPPTCL, these substations are being operated under adequate load.[7]

(3) Operation and Effect Indicators for the MP State transmission system

(i) Installed Transformer Capacity

Table 1: Total Installed Transformer Capacity of the MP State Transmission System

		2010	2016		2020		Contribution of the Project
		Original	Target	Actual	Target	Actual	
Total Installed Transformer Capacity (MVA)	400 kV	4,200	8,610	7,350	8,610	10,595	355
	220 kV	14,030	18,450	21,990	18,450	28,410	960
	132 kV	15,070	18,032	24,056	18,032	31,295	1,139
	Total	33,300	45,092	53,396	45,092	70,300	2,454

Source: MPPTCL

Note: Target values for 2016 were those at the time of the ex-ante evaluation; target values for 2020 are those stated in the *Project Completion Report* (PCR).

Total transformer capacity increased by 30-40% between 2016 and 2020. This was due to the fact that the installed capacity had been increased after the completion of the Project in line with the investment plans of MPPTCL.

(ii) Average Availability Factor

Table 2: Average Availability Factor of MP State Transmission System

		Original 2010	Target 2016	Target 2020	Actual 2020
Average Availability Factor	400 kV transformer	99.05%	98%	98%	99.62%
	220 kV transformer	99.58%	98%	98%	99.02%
	220 kV transmission line	98.22%	98%	98%	99.77%
	132kV transformer	99.84%	98%	98%	99.61%
	132 kV transmission line	98.70%	98%	98%	99.82%
	Whole transmission system	unknown	98%	98%	99.60%

Source: MPPTCL

Note: Target values for 2016 were set by MPERC.

The average availability factor (annual operating hours divided by total annual hours) of transformers and transmission lines exceeded

[4] Relevance: ③, Coherence:③

[5] When providing the sub-rating, Effectiveness and Impacts are to be considered together.

[6] In 37 of the 52 substations, further transformers were added after the Project, adding 2,386 MVA of transformer capacity. In addition, a total of 73 substations were strengthened under the Project, of which 55 substations only got additional bays as transmission lines were laid, and no transformers were added.

[7] MPPTCL considers a load factor of 80% or more for a period of time to be an indication of overload, and if a substation has a load in excess of 80% of capacity for a period of time and further future demand growth is expected, capital investment for additional facility will be considered.

the target value of 98% for all voltage categories. The average value for the entire transmission network was 99.6% in 2020. This was high enough compared to the three states with the largest electricity demand areas in India (Maharashtra, Uttar Pradesh, and Gujarat States).[8] The stability and reliability of the transmission system in MP State is therefore sufficiently high.

Transformers and transmission lines are shut down when equipment is interrupted (tripped) by accidental currents caused by lightning strikes, animal contact, etc. In addition to temporary trips due to the above reasons, the substations included in the Project may also experience trips due to deterioration of disc insulators and current transformers. However, there have been no trips that the average availability of the entire transmission system has fallen below the MPERC standard. It should be noted that, as the substations are also shut down due to regular maintenance for 25-40 hours per year (equivalent to 0.2-0.5% of the annual operating hours), the availability factor never reaches 100%.

Capacity margins and redundancies are always planned in the transmission system so that even if some transformers and transmission lines are taken out of service due to maintenance or tripping, the power supply can be maintained by other facilities.[9] If there is a lack of capacity margin and redundancy, the impact of tripping at one location will be more widespread and take longer to restart. The Project is considered to have contributed to an increase in availability factor by increasing the redundancy of the transmission system.

(iii) Transmission System Loss Rate

Table 3: Transmission System Loss Rate of MP State Transmission System

		Original 2010	Target 2016	Target 2020	Actual 2020
Transmission System Loss Rate	Whole transmission system	3.88%	4% or less	4% or less	2.62%

Source: MPPTCL

The transmission system loss rate of MPPTCL had already met the target at 3.88% in 2010, and the goal at the time of the planning was to continue to maintain that level. In fact, it was further reduced to 2.62% in 2020. This was the lowest compared to the three states with the largest electricity demand regions in India (Maharashtra, Uttar Pradesh, and Gujarat States).10 Therefore, it can be said that the transmission system loss rate in MP State is very low.

Since power losses are proportional to the product of the square of the current (I) and the resistance (R) ($I^2 \times R$) when transmitting power, and since power losses are higher at lower voltages when transmitting the same amount of power, the development of the high-voltage transmission system is linked to lower power losses.[11] It is considered that the development of the transmission system under the Project has contributed to the reduction of the transmission losses. According to estimates by MPPTCL, the transmission loss rate is considered to have been pushed down by about 0.2% as a result of the Project.[12]

On the other hand, MP State has experienced relatively high power losses in the distribution sector, with a distribution loss rate of 24.7% and a combined transmission and distribution loss rate of 27.3% in 2020, which is higher than the all-India average of 20.5%.[13] The transmission and distribution loss rate in the State has improved significantly from 37.6% in 2010, but even so, there is still room for improvement. According to the interview with the MP State Eastern Distribution Company, the high level of electricity theft is pushing up the distribution losses.

(iv) Voltage Fluctuations (additional indicator)

Voltage fluctuation was used as an additional indicator of the quality of electricity service. At the end of 132 kV transmission lines, where the transmission system connects to the electricity grid of the distribution company, it is standard practice to keep the voltage in the range of 132 kV ± 10%. As shown in the table below, the actual results for 2020 are in the appropriate range of +5.6% to -3.4%. The voltage fluctuation range (difference between maximum and minimum voltage) reduced from 9.4% in 2016 to 9.0% in 2022. It is more important to improve the minimum voltage to prevent voltage drops at the customer end, and it can be said that the voltage variability of the transmission system in MP State has indeed improved.

No data were available on voltage fluctuations at the customer end that are connected to the distribution network. But as discussed below, it is inferred that the construction of 132 kV substations closer to the customers load, as realized by the Project, has reduced voltage drops at the customer end.

[8] The transmission system availability in 2020 was 99.67% in Maharashtra State, 99.46% in Uttar Pradesh State and 99.47% in Gujarat State according to the websites of the respective state transmission authorities).

[9] The failure of one unit out of a number (N) of facilities is called an N-1 failure, and the concept of providing redundancy in the facilities so that the supply of electricity is not disrupted in the event of an N-1 failure is called the N-1 standard. This is a concept widely used internationally to ensure a stable supply of electricity, and MPPTCL has also developed its transmission system based on the N-1 standard. For example, if two transformers are installed in the same substation and are normally operated at less than half capacity, transmission can continue even if one of the transformers goes down.

[10] The transmission loss rate in 2020 was 2.94% in Maharashtra, 3.37% in Uttar Pradesh and 3.50% in Gujarat according to the websites of the respective state transmission authorities).

[11] For example, if the same amount of power is transmitted over the same distance, power losses are halved if two transmission lines are used instead of one. In addition, if a new 132 /33kV substation is built close to the demand area, power losses are reduced because the power can be transmitted at a higher voltage closer to the demand area.

[12] The economic analysis at the time of the ex-post evaluation showed an annual saving of Rp 909.1 million due to loss reductions of 145.46 GWh in 2019. The total amount of electricity transmitted in the same year was 71,945 GWh, which means that the transmission loss rate was pushed down by approximately 0.2%.

[13] According to the Central Bank of India's *Handbook on Statistics of Indian States 2021-22*.

Table 4: Voltage Fluctuations of MP State Transmission System

132 kV transmission end maximum and minimum voltage/ fluctuation (%)	Period	Maximum voltage	Volatility	Minimum voltage	Volatility	Range of fluctuation
	Jan.-Dec. 2016	138.9 kV	5.2%	126.4 kV	-4.2%	9.5%
	Jan.-Dec. 2022	139.3 kV	5.6%	127.6 kV	-3.4%	8.9%

Source: MPPTCL

Note: Average of annual maximum and minimum voltage fluctuations at approximately 300 locations of 132 kV transmission end.

(4) Qualitative effects

Based on the explanations of MPPTCL and the operation of the new transmission and substation facilities inspected during the site visit, the Project has contributed to the improvement of liability of electricity supply, reduction of transmission losses, and stable electricity supply as follows.

- Redundancy in transmission and substation facilities allows transmission to continue without problems in the event of breakdowns. For example, by installing a second transformer in a substation with a larger load and operating it with a margin of safety (usually less than half of the substation's capacity), transmission can continue even if one of the transformers goes down. The same effect can be achieved by building a new substation that is connected to a substation with a larger load. In addition, if one transmission line goes out of service, transmission can continue if there is a diversion route. By providing such redundancy in the transmission system, the Project is considered to have contributed to improving the level of grid stability. According to MPPTCL, there has not been a single major grid incident in at least the last 30 years that has caused a partial or total shutdown of the state transmission system. The stable operation of the MP Sate transmission system contributes to the stable transmission of electricity in the western region, which is interconnected by the Central Transmission Utility's high-voltage transmission network.
- Power losses can be reduced by building transmission lines to diversify the transmission path and by building new substations near the demand points. In addition, by constructing new substations and shortening the length of distribution lines to the consumers, voltage drops at the most distant customer end can be reduced. The MPPTCL had previously aimed to extend the distribution lines from 132/33kV substations and other substations with a maximum length of 35 km from the 33kV busbars to the customer end; however, in order to further minimize voltage drops at the customer end, it is currently planning to construct new substations with a goal of limiting the maximum distance to 20 km.[14] Furthermore, connecting multiple substations to the distribution network can reduce the extent of outages in the distribution network and shorten outage times.
- According to MPPTCL, under the central government's policy of promoting electrification, the household electrification rate in MP State increased significantly from 69% in 2015 to 100% in 2019. Until around 2012, there were planned power cuts (load shedding) due to electricity shortages, but for the past decade, there have been no planned power cuts and a 24-hour power supply has been achieved.[15] According to MPPTCL, most of the outages occur in the power distribution network, although data on power outages were not obtained.

Summary of effectiveness

All the set indicators have achieved their targets, to which the Project is considered to have contributed. The transmission system strengthened by the Project is considered to have increased transmission stability through increased redundancy. The construction of substations close to the demand area is considered to have contributed to the improvement of voltage profile at the customer end and reduced power outages. From the above, it is considered that the objectives of the Project have been achieved.

<Impacts>

Electricity use and economic growth in the MP State and Western Region

More than 70% of electricity consumers in MP State are general households. The number of consumers increased by 78% from 9.63 million in 2011 to 18.12 million in 2021. In 2021, agriculture (irrigation) accounted for 47% of electricity consumption in MP State. General households and industry accounted for 27% and 19% respectively. Electricity consumption in 2021 increased by 117% from 2011. By sector, general households increased by 161%, agriculture by 183%, industry by 67%, and others (including commercial) by 20%. The growth in general households and agriculture was significant. Electricity consumption per household increased by 56% from 881 kWh in 2011 to 1,373 kWh in 2021.

The gross state domestic product in 2021 (2011 prices) in MP State increased by 97% from 2011. The breakdown of the gross state domestic product is 35% in agriculture, 25% in industry, and 40% in services (2019).[16]

The Western Region (with a total population of 237 million in 2011)[17] saw electricity demand increase by about 31% from 2.9 billion kWh to 3.8 billion kWh in the period 2012-2020, while gross regional product increased by about 54% over the same period.[18]

[14] Power stepped down to 33 kV at the 132/33 kV substation is fed into the electricity grid of the distribution companies.

[15] Irrigation consumers are supplied with electricity for 10 hours a day.

[16] About half of MP State area is under agricultural cultivation, and about half of the cultivated land is irrigated by deep wells using electricity, mainly for wheat, soy and rice. The state is also actively attracting investment, and a stable electricity supply is considered one of the conditions constituting a favorable investment climate in the state. MP State was ranked fourth out of 28 states in the "2019 Ease of Doing Business Ranking" (Department for Promotion of Industry and Internal Trade, Ministry of Commerce and Industry).

[17] The Western Region includes the five states of MP, Maharashtra, Gujarat, Goa and Chhattisgarh, as well as Union Territory of Dadra and Nagar Haveli and Daman and Diu.

[18] According to the Central Electricity Utility and the National Statistical Office.

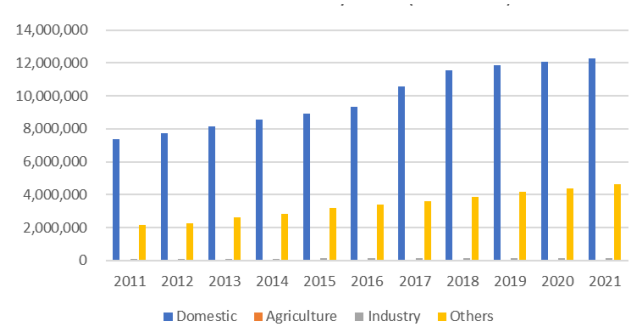


Figure 1: Number of Electricity Users in MP State

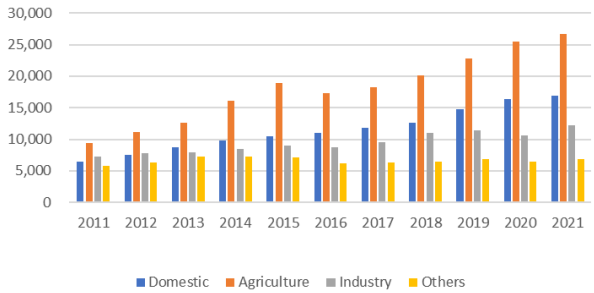


Figure 2: Electricity Consumption of MP State (GWh)

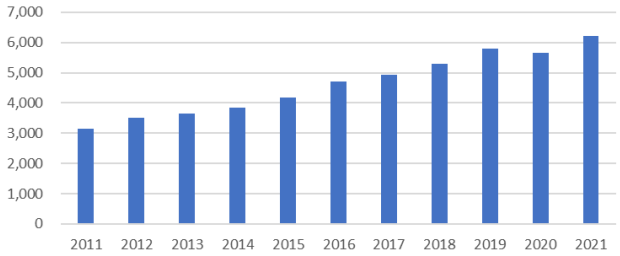


Figure 3: Gross State Domestic Product of MP State (100 million Rp. In 2011 price)

Industry and electricity supply

According to interviews with industries in MP State,[19] stable electricity supply is very useful for industry and, as shown below, direct power supply with the transmission system of MP State is very stable. There has also been some improvement in the supply of electricity through the distribution network, but in some remote areas, there are still frequent power outages due to weak distribution networks.

- According to the Mahakaushal Chamber of Commerce & Industries in western MP State, 10-20 years ago, factories could not operate after evening due to planned power cuts, but now they can operate 24 hours a day. The power situation in the early 2000s was terrible but has improved significantly since then. When the power is supplied directly at higher voltage from the transmission system, the voltage is very stable and interruptions rarely occur. The absence of interruption is very important for factories with production lines that operate 24 hours a day.[20] On the other hand, interruptions still occur when supplied from the electricity distribution network of the distribution companies. In industrial areas, the construction of new substations has reduced the frequency and extent of interruptions and improved voltage profile. This is an important change for industrial development.
- According to the MP State Cold Chain Association, industries in rural areas are more susceptible to frequent power outages in the distribution network than in industrial areas and need to be prepared with generators and other equipment. Voltage fluctuations are also significant, causing inconvenience for refrigerators and freezers.

Night-time light analysis using satellite data

The area around the 53 substations (30 km radius) with 132 kV busbar lines, which were constructed or had transformers added and connected to the distribution network under the Project, was defined as the direct beneficiary area of the Project, and the changes in night-time light intensity before and after the Project were compared with the changes in MP State as a whole. The night-time light intensity in both the direct beneficiary areas and the state as a whole nearly doubled during the 10-year period 2013-2022, and the rate of increase was slightly higher in the direct beneficiary areas. Therefore, the increase in electricity use in the direct beneficiary areas of the Project may have been larger than the increase in the state as a whole. (See the article at the end of the report for details.)

Impact on the natural environment

The Project was considered to fall under Category B, which has a relatively small undesirable impact on the environment and society, in accordance with the *JICA Guidelines for Environmental and Social Considerations* (April 2010).

MPPTCL sometimes hires social and environmental experts as consultants to prepare monitoring reports when required by the project of other donors, but in the case of the Project, preparation of a monitoring report was cancelled after consultation with the JICA India Office. According to the JICA India Office, the Project fell under Category B and was not expected to have a negative impact on the natural environment, and therefore, in consultation with MPPTCL, it was agreed that no specific report would be required. According to MPPTCL, no negative impact of the Project on the natural environment was specifically identified. No negative impacts on the natural environment were identified during the site visits.

Land acquisition, resettlement, etc.

According to MPPTCL, a total of 165 ha of land was acquired for the Project. *Land acquisition was conducted in accordance with JICA*

[19] Interviews were conducted with the Mahakaushal Chamber of Commerce& Industries (Chamber of Commerce in Western MP State), the MP State Cold Chain Association, and SRF (a company that manufactures food paving film in Indore at 132 kV with direct power supply from the transmission system).
[20] According to SRF, it has received continuous supply without a single power outage since the plant started up in 2017, and as the production line, which operates 24 hours a day, takes a week to restart once it stops due to power failure, continuous power supply is very important.

Guidelines for Environmental and Social Considerations. Most of the land acquired was government-owned land and only 5.4 ha of privately-owned land was acquired without any problems. Compensation of Rs 17.5 million (approx. 30 million yen equivalent) was paid to seven landowners in accordance with national law and the compensation policy set by MPPTCL. Compensation was paid in line with government regulations for damage caused by construction works to agricultural and other crops. No specific problems were encountered with land acquisition and compensation, although there were cases where negotiations took time. No resettlement took place.

Other impacts

According to estimates by MPPTCL, the Project saved 145.46 GWh of electricity in 2019 due to the lowered transmission loss rate. This is estimated to have reduced greenhouse gas emissions by approximately 132,000 tonnes per year.[21]

The Project was implemented under a full turnkey contract for the first time in MPPTCL.[22] This was more efficient than the previous practice of having separate contracts for procurement of materials/equipment and construction works.[23] This experience led to the majority of subsequent transmission facility construction projects of MPPTCL being implemented under full turnkey contracts.

According to MPPTCL, there was no notable impact on gender, marginalized people, social systems and norms, human well-being and human rights.

Summary of impact

In the decade since 2011, electricity consumption in the MP State has doubled, with per-household electricity consumption increasing by nearly 60%. The household electrification rate has reached 100%, with the entire population benefiting from electricity. Continuous development of the electricity system, including the Project, has made this possible. In MP State, the power supply for irrigation supports agriculture, which accounts for 35% of the gross domestic product in MP State. The electricity supply is stable and supports industry, particularly in industrial zones and through high-voltage power. From the above, the expected impact of the Project is considered to have been achieved.

<Evaluation Result>

Therefore, the effectiveness and impacts of the project are high.

3 Efficiency

<Output>

Table 6: Planned and Actual Output

	Plan (Note 1)	Actual
New transmission lines	2,142 km	220 kV 341.65 km 132 kV 1,801.58 km (2,143 km in total, 60 routes)
New substations	220 kV substations (8 132 kV substations (26)	220 kV substations (8) 132 kV substations (26)
Substation reinforcement	74 substations (18 with additional transformers) (Note 2)	73 substations (18 with additional transformers) (Note 2)

Source: Prepared by materials provided by MPPTCL and JICA.

Note 1: The number of substations at the time of planning was partly incorrect due to duplication errors and was corrected during the ex-post evaluation.

Note 2: In other substations, additional bays connecting to transmission lines, etc. were constructed.

Due to a faster-than-expected increase in electricity demand in the vicinity of some of the targeted substations, in 2011, MPPTCL partially self-financed the output of the Project first, and replaced the two transmission lines and nine substations originally included in the Project with two other transmission lines and eight substations. Otherwise, the rest of the Project was implemented as planned. Therefore, the actual outputs can be said to be largely in line with the plan.

<Project Cost>

The project cost was planned at JPY 22,213 million (ODA Loan: JPY 18,475 million), but the actual cost was within the plan at JPY 19,659 million (ODA Loan: JPY 12,465 million) (89% of the plan).

[21] Factor calculated from data on the Central Electric Authority website as 0.91 t-CO_2 /MWh.

[22] A full-turnkey contract is a contract in which a single contractor undertakes the entire work of designing facilities and equipment, procuring equipment, materials, and services, construction, and commissioning for a lump sum fixed price and with delivery, warranty, and performance guarantee responsibilities. Until that time, the MPPTCL had been performing the procurement of materials and equipment and construction work under separate contracts.

[23] In the case of separate contracts, it was difficult to successfully match the procurement of materials and equipment with the timing of construction work, resulting in the storage of large amounts of unused stock and loss of stock. Inventory management and other administrative tasks were also difficult.

Table 7: Planned and Actual Project Cost

	Plan (Million Yen)			Actual (Million Yen)		
	JICA	Indian side	Total	JICA	Indian side	Total
Civil works/equipment procurement	16,003	0	16,003	12,465	5,238	17,703
Price escalation	792	0	792	0	0	0
Contingency	1,680	0	1,680	0	0	0
Land acquisition/compensation	0	201	201	0	352	352
Administration	0	934	934	0	1,222	1,222
Taxes	0	2,402	2,402	(Included in civil works costs on the Indian side)		
Interest during construction	0	169	169	0	343	343
Commitment charge	0	32	32	0	40	40
Total	18,475	3,738	22,213	12,465	7,194	19,659

Source: Prepared by materials provided by MPPTCL

<Implementation Period>

The Project was planned to be implemented over a period of 36 months, from the signing of the loan agreement in June 2011 until the commencement of facilities operation in May 2014. In fact, the loan agreement was signed in June 2011 as planned and the Project was implemented over 117 months (325% of the planned period) until the facilities were put into service in February 2021.[24]

<Implementation Issues>

Construction of the Project had started by 2013 under 20 contracts, 16 of which were the first full turnkey contracts for MPPTCL. Most works were completed by 2014 (around 90% of the construction of new substations had been completed), but some works were delayed due to heavy rains in 2013. Some contractors were unable to proceed with the works as contracted due to financial constraints and other factors, and four contracts were canceled in 2015. The remaining works were re-tendered and new construction and materials procurement contracts (five contracts) were awarded in 2016-2017. Some of the works were carried out by MPPTCL's own construction work using procured materials and equipment.

Most of the construction works were completed by the final disbursement date of the loan in September 2018, but one new substation and seven transmission lines could not be completed by then. The delay in the substation was due to the time required to coordinate with the Ministry of Defence, the landowner of the site, while the delay in the transmission lines was due to the fact that it was the left over work from the above-mentioned contract cancellation and construction did not start until 2017 or later, and the time required to negotiate compensation for the right of way of some transmission lines.

<Economic analysis (EIRR)>

At the time of preparation of the ex-ante evaluation sheet, the financial internal rate of return (FIRR) and economic internal rate of return (EIRR) of the Project were calculated to be 14.2% and 18.5%, respectively, based on the following assumptions. The FIRR and EIRR were recalculated based on the actual results for the ex-post evaluation and were 15.1% and 20.8% respectively. The main reason for the higher figures is thought to be that transmission tariffs, which are established based on the costs, are higher than assumed at the time of planning.

Costs: project costs, operation and maintenance costs (economic costs in EIRR)
Benefits: increased transmission revenues, reduced transmission losses
Project life: 30 years

<Evaluation Result>

The above shows that, although the project costs were within the plan, the project period significantly exceeded the plan. Therefore, the efficiency of the Project is moderately low.

4 Sustainability

(1) Policy and System

The results of the electricity reforms, including the unbundling of generation, transmission and distribution and the establishment of MPERC, are well established. In addition, the entry of independent power producers, including solar and wind, and private operators into the transmission sector is underway. MPPTCL is planning, developing and operating the transmission system under the supervision of the state regulator, MPERC. Transmission tariffs are set by MPERC, taking into account the necessary costs.

The above means that there are no policy or institutional challenges to the sustainability of the Project.

(2) Institutional/Organization Aspect

The State Load Dispatch Centre operates the transmission system, including the facilities developed in the Project, in coordination with the power plants, substations, and the three distribution companies for the proper grid operation of the state power system.

There are transmission and substation maintenance teams or maintenance offices (divisions) under the maintenance circles set up in the different regions of the state, which carry out regular maintenance work on transmission lines and substations by patrolling them. For transmission lines, there are 12 maintenance divisions and 37 transmission line maintenance teams under four maintenance circles, and for substations, there are 45 maintenance divisions under 14 maintenance circles. Each maintenance division is staffed by around 30 employees.

[24] The construction contract for the Project includes a one-year warranty period after completion of the facility, while project completion is defined as when the equipment is completed and put into service.

In addition to several engineers and staff from MPPTCL, each substation employs between 10 and 30 external personnel in charge of operation, maintenance, and security, depending on the size of the substation. Regular inspections, checks, and maintenance work are carried out in substations according to manuals on a hourly, daily, quarterly, pre- and post-rainy season, annual, and other regular basis. Daily inspections and work are carried out by personnel stationed at the substation, while pre- and post-rainy season and annual inspections and work are carried out by a team from the maintenance divisions on a roving basis.

The transmission lines are subject to regular visual inspections from the ground (once a month), inspections up on the transmission towers (twice a year), and other inspections as well as necessary maintenance work. After a tripping incident, a site visit is carried out to investigate the cause. Inspections and repairs are also carried out while the power is on using insulated aerial work platform vehicles, etc., and from the air using drones. When relocating transmission towers, relocation work is carried out using temporary transmission towers that can be installed in a short time in order to reduce downtime.

These works are carried out at times and periods of low electricity demand to ensure that the electricity supply is not much affected when the equipment is shut down.

The above has meant that there are no organizational or institutional challenges to the sustainability of the Project.

(3) Technical Aspect

The State Load Dispatch Centre under MPPTCL monitors the operational status of each power plant and transmission system, including solar, wind, and other renewable energy sources, in real time and issues commands to power plants and substations as necessary to ensure stable grid operation. MPPTCL introduced a new SCADA system in 2016, which enables it to constantly monitor the operational status of all transmission and substation facilities in real time, including the power and voltage of each feeder line at each substation, the condition of transformers and other substation equipment, and the location and cause of tripping. The information can be viewed not only on the terminals at each substation, but also on the mobile phones of staff. According to MPPTCL, the introduction of SCADA has contributed to improved and stable operation of the transmission system and reduced transmission loss rates through more efficient operation of transmission facilities. This also incorporates a forecasting system for solar and wind power generation and an automatic electricity demand management system that responds to excessive demand and promptly carries out planned outages and restoration. However, no planned power outages of the kind covered by the system have ever been implemented.

MPPTCL's State Load Dispatch Centre received an award of excellence in the large load dispatch center category at the National Power System Conference in 2022. In addition, some of MPPTCL's substations (35 at the end of 2021) have obtained the international standard (ISO 9001) for quality management.

MPPTCL has been active in introducing new technologies and has so far taken the lead in India in introducing new technologies, such as SCADA and automatic power demand management systems for operations, and insulated aerial work platform vehicles, temporary transmission towers, and inspection drones for maintenance management.

Maintenance manuals are in place for transmission lines and substations, and maintenance and inspection are planned and carried out accordingly. All the results are recorded. For example, all technical information from the time of installation is recorded in one notebook for each transformer, so that the information can be passed on even if the person in charge or the location of the transformer changes.

MPPTCL has a training department, where staff receive repeated training to ensure that they are updated on their skills. External personnel employed at each substation are given training of about three weeks to ensure their technical competence.

From the above, the technical level of MPPTCL is high, and there are no technical challenges to the sustainability of the Project.

(4) Financial Aspect

The table below shows the income and expenditure of MPPTCL for the last three years, with a significant turnaround in operating profit in FY2020, due to the transmission tariff structure being revised retrospectively to the previous year, with part of the previous year's revenue added in FY2020. Note that transmission tariffs are set to cover costs and are approved by MPERC.

Table 8: Financial Status of MPPTCL

(Unit: Rs.10 million)

	FY2019-20	FY2020-21	FY2021-22
Operating income	2,991.81	4,797.55	4,535.49
Operating expenditure	3,220.31	3,644.24	4,220.42
Operating profit	-228.50	1,153.31	315.07
Other income and expenditures	248.13	-1,131.74	763.76
Profit before tax	19.63	21.57	1,078.83

Source: MPPTCL

The operating margin of MPPTCL was negative in 2019, but was high enough at 24% in 2020 and 7% in 2021. The current ratio and debt ratio are both around 80%, and financial security is sufficiently high. Repair and maintenance expenditure of MPPTCL is shown in Table 9. Each maintenance circle calculates the repair and maintenance requirements for the following year and requests a budget. There are no shortfalls in the repair and maintenance budget, partly because transmission tariffs are set taking into account costs.

Table 9: Repair and Maintenance Expenditure of MPPTCL

(Unit: Rs 10 million)

	2019-20	2020-21	2021-22
Repair and maintenance expenditure	77.56	81.56	59.24

Source: MPPTCL

Note: These figures do not include expenditures associates with the State Load Dispatch Center.

The budget for necessary repairs and maintenance has been secured and is expected to be secured in the future. There are no financial challenges related to the sustainability of the Project.

(5) Environmental and Social Aspects

MPPTCL has a system in place for on-site engineer reports any environmental and social problems to headquarters. Therefore, there are no particular challenges on environmental and social aspects.

(6) Preventive Measures to Risks

In cases where an emergency response is required, such as the collapse of a tower or flooding of a substation due to storms, etc., MPPTCL has established a standard response procedure. Repairs will be carried out according to the repair and maintenance budget allocated to the sector concerned. In the actual case of a flooded control room at a substation, the transmission route had been changed beforehand to shut down the equipment and prevent a major power outage. Therefore, the emergency response system is prepared, and there are no particular problems.

(7) Current Status of Operation and Maintenance

The Project's transmission and substation facilities have never required major repairs and are operating properly. The transmission network as a whole is in good working order. Safety management is considered adequate, as safety management notices are posted throughout the substation and training is provided to operators. Manuals are in place, and spare parts are available in the parts storehouse. SCADA screens, telephones, and a list of contact persons for the relevant organizations are in place. A case in which the power distribution network was tripped was observed during the field visit and was quickly responded to by the personnel contacting the relevant offices. Based on the above, the operation and maintenance status of the Project is adequate.

<Evaluation Result>

Therefore, the sustainability of the project effects is high.

III Recommendations & Lessons Learned

(1) Recommendations to Executing Agency

MPPTCL should keep operating and maintaining the outputs of the Project adequately and continue its efforts to ensure a stable electricity supply in the MP State by continuing to develop the necessary transmission network.

(2) Recommendations to JICA

None.

(3) Lessons Learned

- MPPTCL prepared an appropriate master plan and the scope of the Project was prepared and coordinated based on it, which resulted in ensuring consistency with other donor projects, etc. Therefore, when providing financial assistance to augment the system in the power sector or other sectors where a large number of facilities and equipment are operated as an interlinked system, it is important to check whether quality plans are developed using appropriate methods by the executing agency.
- Operation and effect indicators for the Project were set for the system as a whole. As the facilities under the Project functioned as part of the system and it was difficult to measure their effectiveness individually, it was appropriate to set such indicators to determine the degree of achievement of the Project's objectives. However, since it could not be verified how the facilities of the Project alone contributed to the indicators of the system as a whole, this ex-post evaluation confirmed that the substations constructed and enhanced by the Project were properly operated separately from the above indicators. Therefore, in projects where some of the facilities in the system are developed, in order to more explicitly describe the contribution of the project facilities to the overall system, it is recommended that indicators on the status of availability and operation of each such facility should also be set in addition, to the extent that information is available.

VI Non-Score Criteria

Performance

Objective Perspective (none in particular)

Additionality (none in particular)

Switch-yard of substation
(Jabalpur substation: photo by the external evaluator)

Transformer of the Project (front), transformer added later (rear)
(Jabalpur substation: photo by the external evaluator)

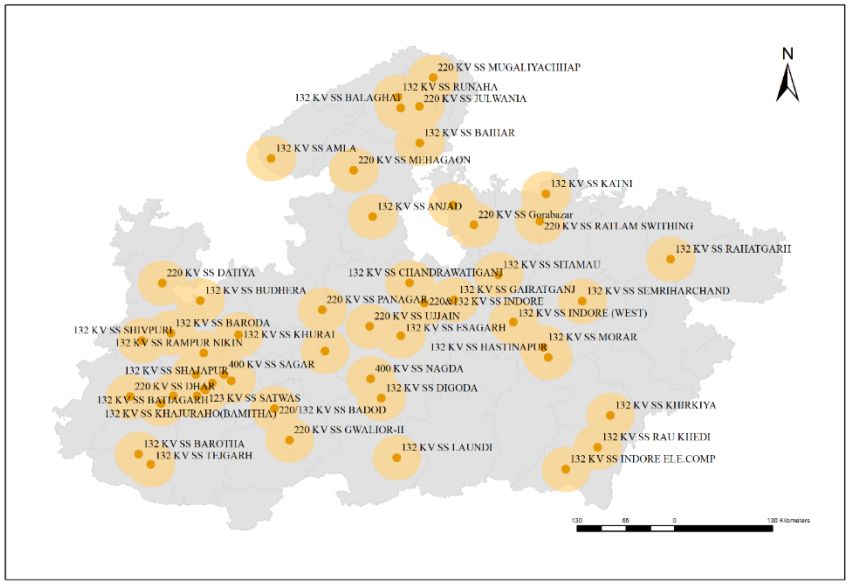
Control room of substation
(Damoh substation: photo by the external evaluator)

SCADA display at substation
(Damoh substation: photo by the external evaluator)

Stock of spare parts at substation
(Gorabazar substation: photo by the external evaluator)

Periodic inspection of transformers
(Dhar substation: photo by the external evaluator)

The area around 53 substations (30 km radius) that was constructed or provided with additional transformers and with 132 kV bus lines connected to the distribution network was defined as the direct beneficiary area of the Project, and the changes in nighttime light intensity before and after the Project were compared with those of the entire state. The OLS (Operational Linescan System) onboard the U.S. military meteorological satellite DMSP (Defense Meteorological Satellite Program) and the VIIRS (Visible Infrared Imaging Radiometer Suite) onboard NASA's earth observation satellite Suomi NPP were used for the analysis.



Source: Material provided by Arthur C Clarke Institute for Modern Technologies

Figure 4: Direct Beneficiary Areas for Nighttime Light Analysis

As shown below, nighttime light intensity in both the direct beneficiary areas and the state as a whole nearly doubled over the 10-year period of 2013-2022, but the rate of increase was slightly greater in the direct beneficiary areas. Thus, it is possible that the increase in electricity use in the direct beneficiary areas of the Project was larger than the statewide increase.

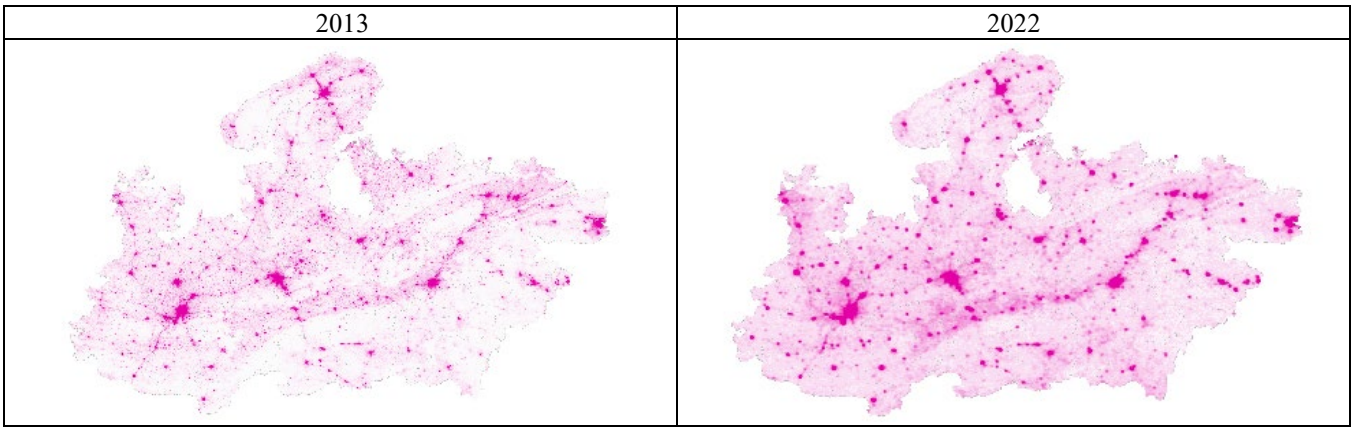
Table 10: Changes in Nighttime Light Intensity: Direct Beneficiary Areas vs. Statewide

(Unit:10^{-8}W/cm^2/sr)

	2013 (a)	2022 (b)	Increase ratio (b/a)
Direct Beneficiary Area	0.60	1.13	188%
Whole State	0.48	0.88	183%

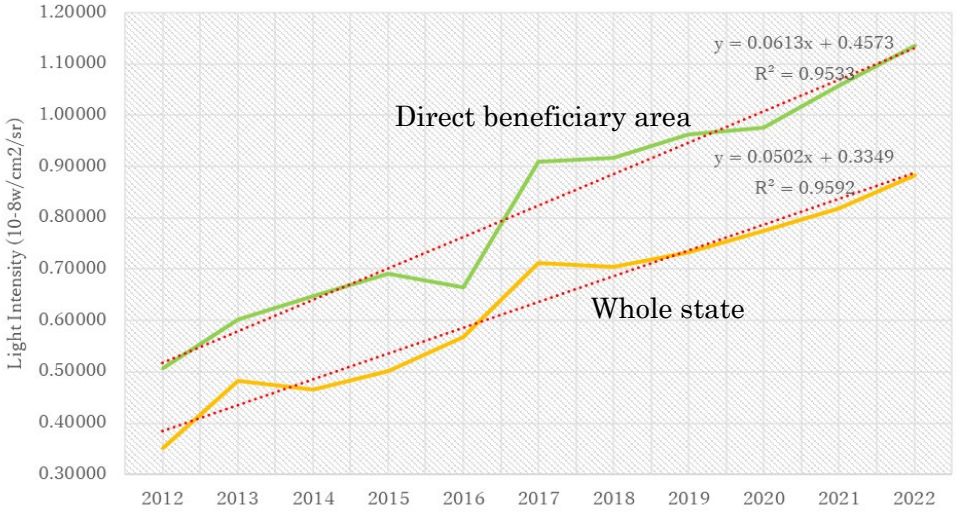
Source: Material provided by Arthur C Clarke Institute for Modern Technologies

[25] This analysis was commissioned by the Arthur C Clarke Institute for Modern Technologies, Sri Lanka.



Source: Material provided by Arthur C Clarke Institute for Modern Technologies

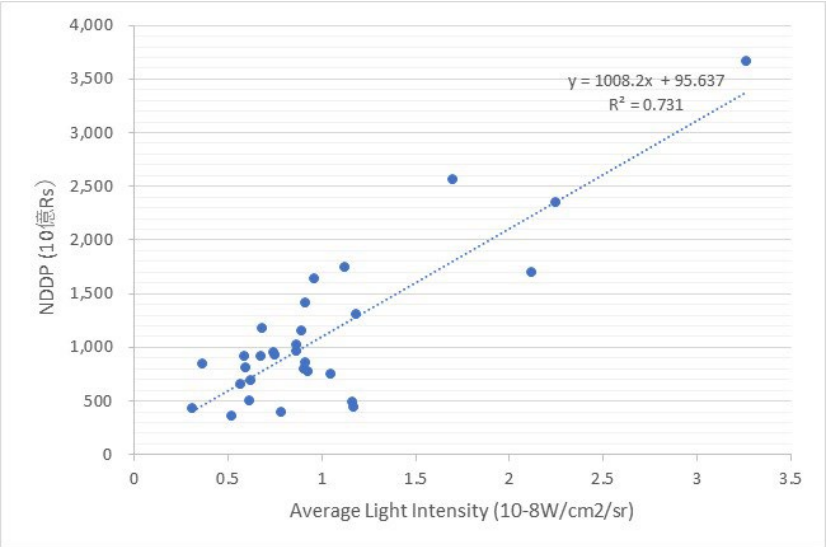
Figure 5: Changes in Nighttime Light in MP State



Source: Material provided by Arthur C Clarke Institute for Modern Technologies

Figure 6: Change over the Years of Nighttime Light

As a reference, the correlation between nighttime light intensity and net district domestic product (NDDP) in the various districts of the state was analyzed, attempting to relate changes in nighttime light to changes in economic activity in the beneficiary areas. There is a strong correlation between NDDP and nighttime light intensity in 2019-2020 (correlation coefficient: 0.73). Assuming this correlation, the increase in nighttime light intensity in the direct beneficiary areas (from 0.60 in 2013 to 1.13 10^{-8}W/cm^2/sr in 2022) corresponds to an increase in NDDP of about 85% (from Rs 62.7 billion to Rs 115.7 billion: data provided by Datanet India Private Ltd.). However, this does not indicate a causal relationship between the two. On the other hand, the statewide increase in nighttime light intensity (from 0.48 in 2013 to 0.88 10^{-8} W/cm^2/sr in 2022) corresponds to an increase in NDDP of about 79% (from Rs. 50.7 to 90.7 billion). This suggests that the NDDP increase in the beneficiary areas is greater than in the state as a whole.



Source: Material provided by Arthur C Clarke Institute for Modern Technologies

Figure 7: Correlation between NDDP and Nighttime Light Intensity (2019-20)