CHAPTER-2
POLICY, PLANNING AND SELECTION OF TECHNOLOGY


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Chapter-2
Policy, Planning and Selection of Technology

2.1 Policy Framework

Policy is a deliberate system of principles to guide decisions and achieve rational outcomes. A policy is a statement of intent and is implemented as a procedure or protocol. Policies can assist in both subjective and objective decision making. Policies usually assist senior management with decisions that must be based on the relative merits of a number of factors and as a result are often hard to test objectively.

Government of India approved (April 2006), the National Urban Transport Policy which *inter-alia,* seeks to promote integrated land use and transport planning, greater use of public transport, non-motorised modes of travel, and use of cleaner technologies. It offers Central Government's financial support for investments in public transport; infrastructure for greater use of non-motorised modes; construction of parking facilities, including demonstrative pilot projects. Accordingly, a common set of guidelines for preparation as well as appraisal of DPR for Mass Transit proposals was circulated (November 2006) to Heads of Metro Corporations across the country by the Ministry of Urban Development (MoUD).

As per sanction letters issued by GoI for Phase-III MRTS Project, equity was to be contributed 50:50 by GoI and GNCTD for corridors within Delhi. For acquisition of land in Delhi and bearing of central taxes, subordinate debt was provided by GoI and GNCTD. Besides, 4.5 *per cent* of project cost was to be funded by earning revenue from property development and about 40 *per cent* of project cost was to be financed through principal loan from the Japan International Cooperation Agency (JICA) at concessional rates by GoI and the same has been transferred to DMRC as Pass Through Assistance[12].

For corridors outside Delhi in the NCR, the entire project cost (except Rolling Stock, which are to be procured by DMRC through its internal accruals) is funded by the respective State Government and the GoI in 80:20 ratio. In the NCR, land is provided free of cost while for bearing of state taxes, subordinate debt is provided by the respective State Governments. Further, there is no funding from loan in NCR extension projects.

Audit reviewed the approval of the initial Phase-III projects having four corridors and nine extension corridor to assess whether effective planning was in place and observed deficiencies as brought out in the following paras.

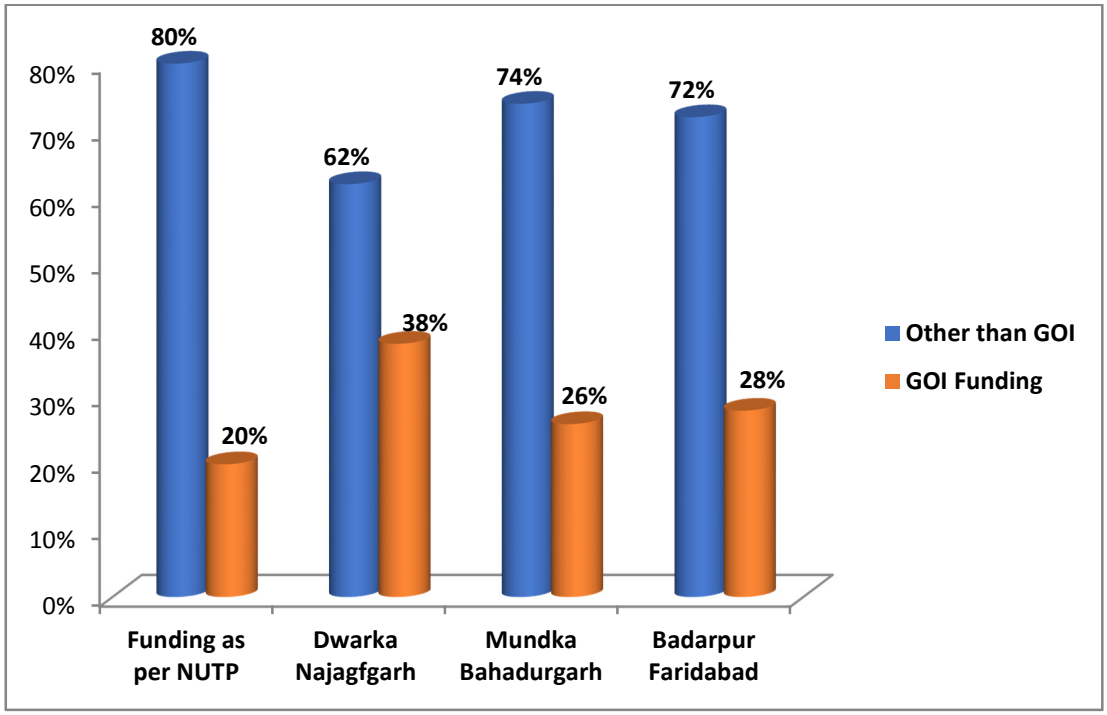
[12] ***Pass Through Assistance is a mechanism through which the GoI obtains loan from JICA in Japanese Yen (JPY) and passes it to DMRC in rupee terms.***

2.1.1 Funding pattern in the DPRs of Phase-III were not in accordance with provisions of National Urban Transport Policy 2006

National Urban Transport Policy stipulated that in the metro rail projects being set up through the mechanism of Special Purpose Vehicle, the Central Government would offer financial support either in the form of equity or one time Viability Gap Funding (VGF) subject to a ceiling of 20 *per cent* of the capital cost of the project (including equity, subordinate debt and grant etc.,) excluding the cost of land and Rehabilitation and Resettlement. DMRC formulated DPRs for Phase-III corridors and extension of metro to NCR towns. The sanction orders issued by the GoI revealed that funding pattern projected in the DPRs of Dwarka-Najafgarh, Mundka-Bahadurgarh and Badarpur-Faridabad corridors were 18 *per cent*, 6 *per cent* and 8 *per cent* in excess over the prescribed ceiling of 20 *per cent* of the project cost. This resulted in excess contribution by GoI amounting to ₹165.92 crore, ₹98.82 crore and ₹156.6 crore for Dwarka-Najafgarh, Mundka-Bahadurgarh and Badarpur-Faridabad corridors, respectively.

Thus, DMRC's funding plan in the DPR was in contravention of National Urban Transport Policy, 2006.

Chart 2.1
Funding pattern in deviation of National Urban Transport Policy



The Ministry/ DMRC in the Exit Conference (11 January 2021) has agreed to implement the funding pattern as per National Urban Transport Policy 2006.

2.1.2 Inconsistency in Financial Internal Rate of Return criteria for approval of corridors

In August 2013, the MoUD instructed that Financial Internal Rate of Return[13] of investment in MRTS projects should preferably be eight *per cent* or more for consideration by the GoI. Prior to this circular (August 2013), there was no minimum criteria of Financial Internal Rate of Return for approval. Accordingly, the MoUD instructed for modification of all DPRs prepared after August 2013 to comply with the criteria of eight *per cent* of Financial Internal Rate of Return.

In compliance, DPRs of (i) Dilshad Garden to Ghaziabad, New Bus Adda, (ii) Noida City Centre to Noida Sec-62, (iii) Kalindi Kunj to Botanical Garden, (iv) YMCA Chowk to Ballabhgarh corridors were revised (up to October/ December[14] 2014) and higher Financial Internal Rate of Returns of 12.23 *per cent*, 8.63 *per cent*, 9.85 *per cent* and 11.01 *per cent* were computed as against the earlier Financial Internal Rate of Return of 4.02 *per cent*, 2.03 *per cent*, 1.11 *per cent* and 4.50 *per cent*, respectively.

In this regard, Audit observed that:

(i) Financial Internal Rate of Return of all the corridors/ sections sanctioned before August 2013 were in the range of 0.08 *per cent* to 6.06 *per cent* except Shiv Vihar and Badarpur-Faridabad extensions which had negative return of ₹755 crore and ₹798 crore, respectively, over the horizon period of 30 years.

(ii) In pre-revised DPRs[15], 15 fare slabs from ₹10 to ₹44 (with a difference of ₹1 to ₹3) were considered while in the revised DPRs, 7 fare slabs from ₹10 to ₹60 (in multiples of ₹10) were considered. For instance, in the pre revised DPRs, fare slabs of ₹19 to ₹24 for the distance of 6 km to 12 km were considered, whereas, in the revised DPRs for the same distance, fare of ₹30 was considered. Consequently, Fare Box Revenue[16] has increased from ₹9,443 crore to ₹19,928 crore (111 *per cent* increase), ₹5,327 crore to ₹12,624 crore (137 *per cent* increase) and ₹2,573 crore to ₹7,066 crore (175 *per cent* increase) in Dilshad Garden to Ghaziabad, Noida City Centre to Noida Sector-62, and Kalindi Kunj to Botanical Garden, respectively. In case of pre revised DPR (January 2013) of Faridabad to Ballabhgarh section, 15 fare slabs in range of ₹11 to ₹40 with escalation factor @ 7.5 per cent for every two year was considered. However, while revising the DPR (December 2014), 15 fare slabs in range of ₹14 to ₹52 with escalation factor @ 15 per cent for every two year was considered resulting in increase in Fare Box Revenue from ₹2,578 crore to ₹6,559 crore (154 *per cent* increase).

(iii) DMRC prepared (December 2014) the feasibility report of Najafgarh-Dhansa Bus Stand but did not revise the Financial Internal Rate of Return of 3.4 *per cent* which was lower than benchmark of eight *per cent* and still recommended it as a viable

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[13] ***An indicator to measure the financial return on investment of an income generation project and is used to make the investment decision***

[14] ***YMCA Chowk (Faridabad) to Ballabhgarh***

[15] ***Dilshad Garden to Ghaziabad, Noida City Centre to Noida Sector-62, and Kalindi Kunj to Botanical Garden***

[16] ***Fare Box Revenue is the revenue collected from passengers through sale of tokens and smart cards***

corridor. Financial Internal Rate of Return was calculated after considering 15 *per cent* escalation after every two years on fare slab as recommended by Third Fare Fixation Committee. The Fourth Fare Fixation Committee in its Report (September 2016) had suggested to DMRC that if no Return on Investment is to be considered, the repayment of loan is to be taken into account for considering the viability of the project. Audit also noticed that the effective rate of interest (after considering foreign exchange fluctuation risk) of JICA loan was 5.20 *per cent*. Hence, considering lower Financial Internal Rate of Return of 3.4 *per cent* than effective rate of interest of 5.20 *per cent* was unjustifiable.

(iv) Resultantly, Financial Internal Rate of Return of five corridors[17] sanctioned from August 2013 to February 2019 were in the range of 8.63 *per cent* to 12.23 *per cent* except Najafgarh-Dhansa Bus Stand (3.4 *per cent*) as detailed in **Annexure-II**.

Thus, out of the 13 corridors proposed for Phase-III, DMRC recommended two financially unviable corridors[18] with negative Financial Internal Rate of Return and one corridor i.e., Najafgarh-Dhansa Bus Stand extension was approved with Financial Internal Rate of Return less than the benchmark of eight *per cent.* In four corridors[19] Financial Internal Rate of Return was enhanced considering inflated Fare Box Revenue to meet out the benchmark of eight *per cent*.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that:

- The Group of Ministers had directed (August 2011) for the Shiv Vihar extension. Accordingly, the proposal was prepared and submitted to the Government despite low ridership.
- The fare slabs with 15 slabs recommended by the Third Fare Fixation Committee were mostly in odd figures and created a lot of problems in tendering change to the passengers at the stations. Accordingly, the new fare structure with seven slabs was included in the revised DPRs.
- GoI realised that achieving the Financial Internal Rate of Return of eight *per cent* is normally difficult and subsequently dispensed with the requirement of Financial Internal Rate of Return and switched over to Economic Internal Rate of Return[20] in the Metro Policy, 2017. DMRC agreed with Audit that lending interest rate including exchange fluctuation should have been quoted for such comparison. However, in this case, loan amount was only 38.32 *per cent* with the balance as equity and subordinate debt. Therefore, the Financial Internal Rate of Return of 3.4 *per cent* on the project cost established its viability even up to the interest rate of 8.87 *per cent* on the loan component.

The reply of the Ministry/ GNCTD/ DMRC is not acceptable as approving of DPRs with negative and low Financial Internal Rate of Return would lead to operational loss

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[17] ***Corridors mentioned at Sl. no. 9 to 13 in Annexure-II***

[18] ***Maujpur-Shiv Vihar and Badarpur-Faridabad***

[19] ***Dilshad Garden to Ghaziabad, Noida City Centre to Noida Sector-62, Kalindi Kunj to Botanical Garden and Faridabad to Ballabhgarh***

[20] ***Economic Internal Rate of Return is the discount rate at which discounted net benefits (Revenue-Cost) equals to zero. It quantifies the financial and non-financial benefits from the investments.***

for DMRC and extra burden on the Government exchequer/ taxpayer's money. The rate of return should be compared with weighted average cost of capital i.e., borrowed fund and equity. DMRC should have prepared DPR with realistic and objective assumptions for computation of Financial Internal Rate of Return based on the fare existing at the time of preparation of DPR with prevailing escalation. Reply of DMRC regarding inclusion of new fare structure with seven slabs in the revised DPRs (October 2014) is not tenable as in case of revised DPR for YMCA Chowk to Ballabhgarh (December 2014), DMRC continued to consider 15 slabs. Besides, Audit also noticed that currently 70 *per cent* (approximately) of commuters use smart cards, where the need for tendering of change is largely minimised.

2.1.3 Non-formulation of various policies by DMRC

Policies are standing plans that provide guidelines for decision making. It establishes the boundaries or limits within which decisions are to be made. Various policies/ procedures/ practices adopted by DMRC in preparation of cost estimates, taking decisions on selection and modification of routes, distance between inter change stations etc., have been reviewed by Audit along with the Technical Consultant (IIT Delhi) and the following is observed:

(i) There is no protocol in DMRC for estimating the cost of an upcoming project in a scientific manner. Rather, DMRC uses the concept of derivation of cost estimate based on 'similar project'. Also, the coefficients in the Price Variation Clause formulas are applied uniformly across all types of projects irrespective of whether they are at grade, underground, or elevated.

DMRC while accepting the observation stated that in the Phase-IV contracts, estimates are being prepared by enhancing the Last Accepted Rates based on Price Variation Clause formulas available in the contracts.

(ii) There is no approved policy on the selection of type of corridor i.e., elevated, at grade or underground.

DMRC responded that type of alignment is decided based on the Right of Way of the road, traffic on the road and other factors like Archaeological Survey of India monuments in the area, localities wherein the corridor passes through etc.

DMRC needs to formulate a policy document on the selection of type of corridor and should also clearly indicate the circumstances under which deviations are allowed.

(iii) There is no approved policy of permissible ground water lowering[21] while constructing underground structures in the absence of which decisions are going to be subjective and may not always result in optimal solution.

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[21] ***Permissible ground water: Normally underground construction below groundwater table will face certain problems. To facilitate the construction, DMRC allows to do the lowering of water table by dewatering systems at a locality based on assessment. This temporary lowering is known as "permissible ground water lowering". But lowering should not disturb the ecosystem and habitat of the area.***

DMRC did not provide specific reply to the point.

(iv) There is no approved policy for providing interchange between two stations and mode of interchange facility. For instance, Dhaula Kuan-Durga Bai Deshmukh South Campus interchange (1.2 km length) was constructed with additional expenditure of ₹73.17 crore over DPR provision of ₹5.25 crore which indicates poor planning and absence of an approved policy in this regard.

DMRC replied that as per the DPR, Dhaula Kuan station was planned at an isolated location with no habitation nearby. Therefore, the station was shifted towards a location with many colleges and residential areas, which resulted in increase in the length of interchange. However, it was not clear under which premise/ assumption the station was planned in a forest area in the DPR in the first place.

2.1.4 Formulation of Detailed Project Reports of Phase-III corridors

Audit reviewed the DPR of the initial Phase-III project of four corridors and DPRs for nine NCR/ other extensions executed during Phase-III, and observed the following deficiencies:

2.1.4.1 Gross infirmities and adoption of different assumptions in the formulation of DPRs

The MoUD issued (01 November 2006) guidelines[22] for preparation of DPR for Integrated Mass Transit System Development Plan. In this regard, Audit observed that:

(i) As per the guidelines, a Comprehensive Mobility Plan[23] is a prerequisite for planning metro rail in any city. A chapter on Comprehensive Mobility Plan highlighting developing an integrated plan was to be included in the DPRs. However, no chapter on Comprehensive Mobility Plan highlighting developing an integrated plan was included in the Phase-III DPR formulated by DMRC. Resultantly, integrated planning with respect to land use and transport, integration of various modes (fares, routes, and facilities) and institutional framework for coordination was not ensured by DMRC.

(ii) Cost and benefit analysis of the adopted technologies was not conducted and incorporated in the DPRs by DMRC during Phase-III of MRTS project, although this was a requirement under Para 4.3 'Alternative Analysis' of the above guidelines.

(iii) Delhi Metro Master Plan was prepared by DMRC for guidance in planning the expansion of the network and the DPR. However, this was not approved by the Board of Directors or Managing Director of DMRC.

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[22] ***The guidelines inter-alia stipulates that based on the plan outline, projects are to be detailed out, conceptually designed, costs worked out, financial and economic feasibility examined and environmental and social impacts analysed and mitigation measures planned. This would include overall funding plan, including risk analysis.***

[23] ***"Comprehensive Mobility Plan" is a plan for improvement and promotion of public transport, non motorised vehicles and pedestrians. It also provides a recognised and effective platform for integrating land use and transport planning.***

(iv) Guidelines/ instructions/ Standard Operating Procedures were not formulated by DMRC for preparation of the DPRs.

(v) Detailed Project Reports were prepared on different assumptions **(Annexure III A & B)**. Replacement cost (after 20 years) of Signalling and Telecom equipment considered in the DPRs **(Annexure-III A)** ranged from 10 *per cent* to 50 *per cent*. Similarly, replacement cost of electrical equipment ranged from 10 *per cent* to 25 *per cent*. Besides, escalation factors of 5 *per cent* and 7.5 *per cent* were considered for calculating Operation & Maintenance cost. No justification was given for the different assumptions in various DPRs. While estimating Fare Box Revenue, DMRC did not consider 10 *per cent* discount on every journey made through contactless smart card, resulting into higher projection of Fare Box Revenue by 7 *per cent.*

(vi) The revised DPRs[24] were not approved by the Board of Directors. Since the original DPRs were approved by Board of Directors, it is imperative that revised DPRs are also got approved by Board of Directors.

Thus, DPRs prepared by DMRC were not in conformity with Guidelines (2006) of MoUD for preparation of DPR and in the absence of any internal guidelines/ Standard Operating Procedures of DMRC for preparation of DPRs, DPRs were prepared on different assumptions.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that the corridors recommended for metro in the DPR were as suggested in the Comprehensive Transport and Traffic Study Report prepared by RITES. Hence, no chapter on Comprehensive Mobility Plan was incorporated in the DPRs. DMRC claimed that cost benefit analysis of the adopted technology and the implementation Plan of Phase-III corridors were incorporated in the Project Viability chapter in the DPR. It stated that Delhi Metro Master Plan is not an approved document by the Board of Directors or Managing Director, DMRC, but only a guideline for planning future metro network. It is further replied that the sanction of Phase-III including its various extensions to NCR was not done in one go. While original project of Phase-III of Delhi MRTS project was sanctioned on 26 September 2011, its extensions to NCR were sanctioned subsequently on different dates. The concerned State Government and not DMRC has to approve the DPR, and the discount of 10 *per cent* does not change the Fare Box Revenue significantly.

The reply of the Ministry/ GNCTD/ DMRC is not tenable because Comprehensive Mobility Plan chapter in DPR was meant for integrated planning and not for recommendation of corridors. While the Viability Chapter of DPR highlights the estimated cost of the project, revenue projections for computation of Financial Internal Rate of Return, Economic Internal Rate of Return etc., it does not have any information of cost benefit analysis of adopted technology[25]. Since Delhi Metro Master Plan is a guideline for planning future metro network, it has to be approved by the Managing

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[24] ***i)Dilshad Garden to Ghaziabad, New Bus Adda, (ii) Noida City Centre to Noida Sec-62, (iii) Kalindi Kunj metro to Botanical Garden, (iv) YMCA Chowk to Ballabhgarh***

[25] ***Like Communication Based Train Control, Platform Screen Door, Unattended Train Operation etc.***

Director or Board for efficient and effective implementation. As all the DPRs mentioned in the **Annexure-III (A & B)** pertained to Phase-III of Delhi MRTS, uniform and consistent assumptions should have been followed in their preparation which should be based on some policy, guidelines, or Standard Operating Procedure.

2.1.4.2 Preparation of Detailed Project Reports in contravention of Working Group on Urban Transport guidelines

The Planning Commission had constituted (18 May 2011) a Working Group on Urban Transport under the Chairmanship of then Managing Director, DMRC to make recommendations on urban transport for the 12th Five Year Plan. Terms of reference include determination of broad norms for selecting the different mode of transport in Indian cities. The recommendations (September 2011) specified the eligibility guidelines for the choice of different mode of transport, which is as follows:

For Metro Rail:

(a) Peak Hour Peak Direction Traffic [26] in 2021 should be >= 15,000 for at least 5 km continuous length;

(b) Population as per 2011 census should be >=2 million

For Bus Rapid Transit System:

(a) Peak Hour Peak Direction Traffic in 2021 should between 4,000 to 20,000

(b) Population as per 2011 census should be > 1 million

Further, as per the RITES traffic study (October 2010), for Peak Hour Peak Direction Traffic up to 20,000 (in 2021), Bus Rapid Transit System and for Peak Hour Peak Direction Traffic up to 30,000 (2031), Light metro can be proposed.

In this regard, Audit observed that:

(i) In case of Dwarka-Najafgarh corridor, Peak Hour Peak Direction Traffic of 5,780 and 10,373 in the year 2021 was assessed by RITES (October 2010) and DPR (March 2009), respectively. Further, as per 2011 census, the population of Najafgarh was 13.65 lakh. However, the proposal for Bus Rapid Transit System/ Light metro was not explored before sending the DPR to the MoUD/ GNCTD for approval.

(ii) In case of Mundka-Bahadurgarh corridor, average Peak Hour Peak Direction Traffic of entire section during the year 2021 was estimated as 6,817. As per 2011 census, the population of Bahadurgarh was 1.78 lakh. However, the proposal of Light metro/ Bus Rapid Transit was not explored before sending the DPR to MoUD/ Government of Haryana for approval.

(iii) In case of Maujpur-Shiv Vihar extension, Peak Hour Peak Direction Traffic at Shiv Vihar and Gokulpuri was only 1,805 and 3,935, respectively, in the year 2021 and the population was 63,752 only[27]. Hence, this stretch did not qualify for any mode of

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[26] ***means the number of passenger trip in one peak hour***

[27] ***As per RITES traffic study report October 2010 of Shiv Vihar***

transport according to the recommendations of the Working Group on Urban Transport guidelines.

(iv) Thus, DPR of above corridors prepared[28] and submitted (after September 2011) by DMRC to the Ministry did not meet the eligibility criteria for choice of different modes of transport, recommended by the Working Group on Urban Transport and RITES Traffic Study. Further, based on projected Peak Hour Peak Direction Traffic, other modes of transport like Light Metro/ Bus Rapid Transit were not explored. While the sanctioned cost of Dwarka-Najafgarh, Mundka-Bahadurgarh and Shiv Vihar extension were ₹1,070 crore, ₹1,991.61 crore and ₹437.85 crore, respectively, DMRC did not furnish line/ corridor wise actual expenditure. As per DPR of Phase-IV MRTS Project, capital expenditure for construction of 1 km Heavy Metro, Light metro and Bus Rapid Transit are ₹250 crore, ₹175 crore and ₹20 crore respectively. Similarly, annual operation & maintenance expenditure for operating Heavy Metro, Light Metro and Bus Rapid Transit will also be in descending order.

Thus, DPRs prepared by DMRC were in contravention of guidelines of Working Group on Urban Transport and RITES study regarding selection of mode of transport on the basis of Peak Hour Peak Direction Traffic and the population criteria. This has resulted in infusing high capital into the projects and consequent higher operation and maintenance cost.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that the recommendations of the Working Group on Urban Transport are only for guidance and were applicable for selection of mode of urban transport for a city as a whole. The recommendations of a mode are to be made after considering techno-economic factor. Detailed Project Reports were prepared as per directives of the respective State Governments in-spite of low ridership and not in line with the recommendations of Working Group on Urban Transport. Light Metro is the same as Medium or Heavy Metro but with reduced train length i.e., four coaches or three coaches instead of eight/ six coaches. Bus Rapid Transit system can carry maximum Peak Hour Peak Direction Traffic of only up to 6,000 to 8,000 while for Mundka-Bahadurgarh, the projected Peak Hour Peak Direction Traffic was 9,883 in 2016 and 21,168 in 2026. DMRC also claimed that the Bus Rapid Transit could be sufficient for a few years but cannot be relied upon for seamless connectivity.

The reply of DMRC is not tenable as the Working Group on Urban Transport guidelines did not specify a single mode of urban transport for an entire city. Further, without conducting the techno-economic evaluation of other modes of transport like Light metro/ Bus Rapid Transit System, which have comparatively low cost, DMRC concluded that heavy metro was the most suitable option despite the low Peak Hour Peak Direction Traffic on these corridors. In case of Mundka-Bahadurgarh section, the projected Peak Hour Peak Direction Traffic of 21,168 in 2026 is only for 1 km stretch

[28] ***DPR prepared for Dwarka-Najafgarh in March 2009 and Mundka-Bahadurgarh in April 2012. The same were sent to Ministry for approval in October 2011 and April 2012, respectively***

and reduces to 1,673 at the last station. However, the actual Peak Hour Peak Direction Traffic of the entire section in December 2019 was only 2,558. There is also a huge difference between MRTS and Bus Rapid Transit System in terms of capital cost. The differences between Light Metro and Heavy Metro are not only in terms of reduced train length but also in terms of length of platform (185 meter/ 90 meter), width of car (3.2 meter/ 2.7 meter), and length of car (22 meter/ 18 meter) etc., which may cost almost half or less than the cost of elevated metro[29]. DMRC in its 86th Board meeting (December 2011) and Empowered Committee meeting (January 2012) had also stated that a heavy metro is not really justified for this level of traffic at Dwarka-Najafgarh. Yet, DMRC designed and constructed all civil structures for Heavy Metro.

2.1.4.3 Inconsistency in traffic estimation/ data in Detailed Project Report

(i) Dwarka-Najafgarh: As per the DPR, projected daily passenger ridership of Dwarka-Najafgarh corridor was estimated as 1,01,867 (2021), while table 9.3 of the same DPR mentioned it as 61,000 (2021). Projected ridership of 61,000 was considered in 2020-21 for calculation of Financial Internal Rate of Return. Thus, there was significant inconsistency in projected ridership in the DPR, which remained unreconciled before submission to MoUD for approval. The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that traffic estimation was done by one of the best available agencies, namely, Central Road Research Institute. Further, this estimation was moderated since the projected ridership of the earlier phase did not materialise.

The reply of the Ministry/ GNCTD/ DMRC is not acceptable as no details/ methodology of moderation was mentioned in the DPR of Dwarka-Najafgarh and the same moderation was not done in any of the DPRs prepared for Phase-III corridors. All the system planning like traction system, signalling system and rolling stock system were done on the basis of 1,01,867 ridership/ 10,373 Peak Hours Peak Direction Traffic. Incidentally, the actual ridership on the section from October-December 2019 was 12,012 only i.e., 12.37 *per cent* of the projected ridership of 97,070 in 2019-20.

(ii) Najafgarh-Dhansa Bus Stand: As per the MoUD guidelines (November 2006), DPR should contain travel characteristics based on primary survey data, and present travel patterns to forecast the future travel demand. But DMRC did not conduct any traffic survey for the Najafgarh-Dhansa Bus Stand section. Feasibility Report of Najafgarh-Dhansa Bus Stand was circulated (October 2016) to NITI Aayog (erstwhile Planning Commission) and other ministries for appraisal. NITI Aayog objected that the Peak Hour Peak Direction Traffic data are not provided in the Public Investment Board note, which was in-contravention of benchmark of Metro Policy 2013. DMRC responded (October 2016) to NITI Aayog that maximum Peak Hour Peak Direction Traffic anywhere on Line-3 is to be considered for this stretch as Najafgarh-Dhansa Bus Stand is the extension of Line-3 where maximum Peak Hour Peak Direction Traffic of 50,000 is being achieved by October 2016. DMRC did not intimate NITI Aayog that

[29] ***As per DPR of Kirti Nagar-Bamnoli (Dwarka) prepared in 2019***

as per RITES study, Peak Hour Peak Direction Traffic was assessed as 2,394 while it was stated as 10,373 (2021) in the Feasibility Report.

The Ministry/ GNCTD and DMRC accepted (January 2021) that traffic survey was not conducted for Najafgarh-Dhansa Bus Stand section as the catchment area remained the same. The reply of DMRC regarding Peak Hour Peak Direction Traffic is not acceptable as it vary from station to station and is estimated only after traffic study. Further, Najafgarh-Dhansa Bus Stand is not an extension of Line-3, but a standalone corridor i.e., Line-9.

2.1.4.4 Other observations on preparation of Detailed Project Report

Audit along with the Technical Consultant (IIT Delhi) observed that the DPR of initial Phase-III (February 2011) corridors did not have information or had minimal information on the following:

- tunnel details, cut and cover method, tunnelling methods, support system, lining, excavation methods etc;
- geological and geotechnical investigations methods mentioned in the DPR are general in nature and information about rock and rock mass properties which are essential for the foundations, tunnel design, ramps, support system were not found mentioned.
- excavation methodology including selection of suitable Earth Pressure Boring Machine, Tunnel Boring Machine or mixed type of system, would depend on the strata and their mechanical properties which were missing in the DPR; and
- quick and cost-effective geophysical methods to get the strata condition depth wise along the alignment were also not mentioned.

The Ministry/ GNCTD and DMRC agreed (January 2021 and July 2020) to the suggestions for further improvements in the DPRs as stated above.

2.1.4.5 Non-consideration of Planning Commission observations

The DPR (Mundka-Bahadurgarh) was circulated (November 2011) to Planning Commission and other ministries for appraisal. The Planning Commission raised (May 2012) various observations like (a) Reconsideration of metro on this corridor on the basis of low Peak Hour Peak Direction Traffic; (b) At least 4.5 *per cent* of the cost to be recovered under Property Development; (c) Inconsistency in per capita trip rates used for Delhi and Bahadurgarh region; and (d) Dropping of last metro station at City Park due to very low level of traffic etc. In response, DMRC stated that this extension corridor is proposed on Transit Oriented Development concept that wherever metro goes, development follows.

In this regard, Audit observed that except for a residential project constructed by DMRC at NSIC Okhla station on Line-8 no other instance of metro lines based on Transit Oriented Development was noticed.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that all observations of Planning Commission were complied with and incorporated in the revised DPR submitted to GoI in April 2012.

The reply of the Ministry/ GNCTD/ DMRC is not acceptable as all the above issues persist in the revised DPR submitted in April 2012. Further, DMRC accepted that the actual traffic on this corridor has not been achieved as development along the corridor has not taken place as was envisaged.

2.1.4.6 Excess estimation of ₹138.40 crore for acquisition of private land

Detailed Project Report Phase-III provides that private land for Mass Rapid Transit System project shall be acquired by the GNCTD and compensation shall be paid as per Land Acquisition Act, 1894. The average rate of private land was computed as ₹34,500 per square meter (sqm) based on awards issued for four cases (three industrial and one commercial) during 2009-10. In this regard, Audit observed that:

i. Corridor-wise location of required land including area, land use and ownership has been mentioned in the DPR and the Social Impact Assessment study. However, DMRC had estimated the land rates for entire corridors of Phase-III based on four locations of South Delhi instead of estimating the cost of land based on land usage like residential, industrial, commercial, agricultural etc.

ii. The cost of land acquired (December 2009) at Harkesh Nagar taken for estimation purpose, included cost of structures of ₹2.09 crore also. However, the cost of the structure was not excluded by DMRC while computing the land rate of ₹34,500 per sqm. After excluding the same, the average land rate comes to ₹31,365.69 per sqm. Thus, there was higher estimation of land cost of ₹11.12 crore due to adoption of higher land rate.

iii. Detailed Project Report of Dwarka-Najafgarh (March 2009) states that private land of 5.98 hectare required for alignment, station and Property Development from chainage 4,400 meter to 5,600 meter which is an agricultural land. As per GNCTD circular (24 January 2008), the agricultural land rate applicable was ₹53 lakh per acre. However, DMRC applied (March 2009/ April 2012), the rate of ₹8.09 crore/ ₹8.21 crore per acre[30] instead of ₹53 lakh per acre in the DPR of Dwarka-Najafgarh and Mundka-Bahdurgarh (Delhi portion), respectively. This resulted in over-estimation of land cost by ₹104.48 crore for Dwarka-Najafgarh corridor and ₹22.80 crore for Mundka-Bahadurgarh. In the subsequent land award (October 2012) of Urban Extension Road II near Mundka Industrial Area Station and land award (December 2013) of Greater Kailash land (Phase-III), agricultural land rate of ₹53 lakh per acre was considered.

Thus, DMRC did not prepare cost estimation for land in the DPRs after considering actual land usage and applicable land rates. This resulted in excess estimation and sanctioning of higher funds for the corridors.

[30] ***₹20 crore and ₹20.29 crore per hectare (equivalent to 2.47105 acre) as mentioned in DPR of Dwarka-Najafgarh and Mundka-Bahadurgarh corridor, respectively.***

The Ministry/ GNCTD and DMRC replied (July 2020 and January 2021) that the detailed survey of location and adjacent area is being determined after approval of the project as the exact/ detailed assessment of the land requirement from all the land categories is not possible during DPR stage. Private land at Dwarka-Najafgarh corridor acquired by DMRC was under residential use and it was not possible to procure the land by offering agriculture rate.

The Ministry/ GNCTD/ DMRC acknowledged that detailed assessment based on land usage is done after approval of the project. DMRC did not provide the supporting documents relating to land usage as 'Residential' as mentioned in the reply. The reply of DMRC is silent on the land acquisition award pronounced for land near Mundka Industrial Area station and Greater Kailash station, which were based on land usage (viz. agricultural). The reply was also silent on inclusion of structure cost for estimation of land. Thus, DMRC's preparation of cost estimation of private lands was flawed leading to excess estimation of ₹138.40 crore.

2.1.4.7 Excess estimation of ₹142.11 crore of Rehabilitation and Resettlement activities

Social Impact Assessment study of initial Phase-III corridors was conducted (June 2011) by RITES on behalf of DMRC after approval of DPR by the Board of Directors.

Audit observed that as per the Social Impact Assessment study, total cost of Rehabilitation and Resettlement activities on initial Phase-III corridors (four corridors) was ₹182.51 crore on the basis of land cost of ₹34,500 per sqm and construction cost as mentioned in the DPR. However, DMRC estimated ₹324.62 crore for Rehabilitation and Resettlement including hutments and road restoration, etc., on lump sum basis which was submitted to and approved by the MoUD on 26 September 2011. DMRC's estimation for Rehabilitation and Resettlement activities in the DPR was thus higher by ₹142.11 crore than that estimated in the Social Impact Assessment study. Despite vigorous pursuance, DMRC did not provide the details of amount paid for resettlement against the estimated amount.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that in the DPR, DMRC estimated ₹324.62 crore for Rehabilitation and Resettlement including hutments and road restoration etc., on lump-sum basis whereas in Social Impact Assessment report, cost of road restoration work, and cost of Government land was not included.

The reply of the Ministry/ GNCTD/ DMRC is not acceptable as Rehabilitation and Resettlement computed in DPR was not based on any scientific method, whereas Rehabilitation and Resettlement estimates in Social Impact Assessment were calculated after considering Government guidelines relating to eligibility for rehabilitation of project affected persons and average awarded rates of private land in the past. The cost of road restoration is part of civil work and cost of the Government land was already included in the land estimation in the DPR.

2.2 Planning Process adopted for Phase-III Projects

Planning is an organisational management activity for setting priorities, distributing resources, strengthening operations, and ensuring achievement of common goals. DMRC's planning work not only covers their core work of construction and operation of metro rail services, but also consultancy services to other metro organisations in India and neighbouring countries.

DMRC has a separate Planning Department whose core activities are coordination with various departments of DMRC, liasioning with MoHUA and GNCTD, attending to Parliament questions etc. The preparation of DPRs and other studies, which are essential for planning of MRTS projects are carried out by the Consultancy Division of DMRC. The core activities in Consultancy Division are carried out by the officers/ staff of DMRC, while activities like Traffic Survey, Topographical Survey, Environmental Impact Assessment and Social Impact Analysis and Geo technical investigations are outsourced. Based on the data obtained from the studies/ surveys, DMRC prepared DPR for Phase-III and the extensions of metro to various NCR towns. The basic parameters adopted for selection of project and formulation of DPR are Delhi's high population growth rate, high economic growth rate, and the excessive pressure on the city's existing transport system. The DPRs formulated by the Consultancy Division are approved by the Board of Directors and submitted to the MoHUA and GNCTD. Ministry of Housing and Urban Affairs then forwards the DPRs to Niti Aayog (erstwhile Planning Commission) and various Ministries[31] and departments for their views, comments and remarks which are then shared with DMRC for inclusion in the DPRs. Detailed Project Reports are also revised based on guidelines and further directions of the MoHUA and GNCTD. The Planning Department is headed by Director (Project and Planning) and Consultancy Division is headed by Director (Business Development).

DMRC initiated the work of preparation of Phase-III DPR in 2008. The initial DPR was submitted to the GNCTD and the GoI in March 2010. However, based on the traffic study report submitted (October 2010) by RITES and suggestions of GNCTD, revised DPR was sent (09/ 11 February 2011) to the MoHUA and the GNCTD for approval. The implementation of metro Phase-III was approved by Board of Directors in its 83th meeting (8 March 2011) and by GNCTD on 11 April 2011. The Empowered Committee and Empowered Group of Ministers (EGoM) approved the Phase-III of Delhi MRTS project on 26 April 2011 and 09 August 2011, respectively. The sanction of the President of India was accorded (26 September 2011) for implementation of Phase-III of Delhi MRTS project with four corridors[32] of 103.05 km length at an estimated completion cost of ₹35,242 crore over a period of five years. The same was further extended to 160.76 km (sanctioned cost of ₹48,565.12 crore) after sanctioning

[31] ***Ministry of Finance, Ministry of Railways, Ministry of Home Affairs and other concerned Ministries***

[32] ***comprising of two new corridors i.e., Line-7 and Line-8 and two extensions of existing lines i.e., Line-2 extension and Line-6 extension***

of nine more sections/ corridors by the GoI. The DPRs of the nine sections/ corridors were also prepared by DMRC.

In this regard, Audit observed the following about planning aspects in DMRC.

2.2.1 Non-signing of Memorandum of Understanding for implementation of Phase-III

As per sanction letters of Phase-I and Phase-II of Delhi MRTS projects, operational loss, if any, was to be borne equally by GoI and GNCTD. However, as per the sanction letter of Phase-III, the entire operational loss was to be borne by the GNCTD and a Memorandum of Understanding (MoU) was to be signed amongst the GoI, GNCTD and DMRC to ensure effective implementation of the project and conditions of sanction. The MoU was yet to be signed (February 2021).

2.2.2 Non recovery of ₹63.27 crore due to non-signing of Memorandum of Understanding with Government of Uttar Pradesh

The Ministry of Urban Development (MoUD) sanctioned (September 2012) the Maujpur-Shiv Vihar extension. As per Paragraph 2 (c) of sanction letter, a MoU shall be signed by DMRC with Government of Uttar Pradesh (GoUP) to ensure effective implementation of the project. DMRC forwarded (March 2013) the draft MoU for approval to GoUP. DMRC also apprised (November 2018) the Chief Secretary, GoUP that it had constructed the portion in Uttar Pradesh by diverting its own funds provided for Delhi State, and that these funds were immediately required for the work execution within Delhi. However, the Special Secretary, GoUP stated (January 2019) that there was no MoU between DMRC and the Ghaziabad Development Authority (GDA) in this regard, and hence there is no rationale for releasing the fund by the GDA for this corridor. Audit observed that after completion of construction work, the section has been opened (October 2018) for public, but the approval of MoU from GoUP and release of funds was still awaited. DMRC had utilised ₹63.27 crore for construction of corridor in the Uttar Pradesh portion which were earmarked for other corridors.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that DMRC has been pursuing with the GoUP/ GDA for release of funds of ₹63.27 crore and admitted that no amount has been received till date from GoUP**.**

2.2.3 Execution of unviable corridors

(i) Execution of Dwarka-Najafgarh corridor with net cash outflow of ₹5,178 crore

As per the DPR, Dwarka-Najafgarh metro corridor was not financially viable. To make the corridor viable, a provision of 4.03 hectare of land at Najafgarh station was included for Property Development. The same was to be made available by GNCTD to DMRC. Without income from Property Development during the horizon period of 33 years, DMRC assessed negative cash flow of ₹5,178 crore (i.e., total cash outflow/ total cost of ₹7,504 crore minus total revenue of ₹2,326 crore). However, after considering net Property Development revenue of ₹5,675 crore, Financial Internal Rate of Return was

estimated as 1.18 *per cent* over the horizon period with estimated net cash inflow of ₹125 crore. The corridor was approved (September 2012) by the MoUD at the cost of ₹1,070 crore and was to be completed by 2015 (actual completion in October 2019).

Audit observed that DMRC had assumed that 4.03 hectare land area would be made available by GNCTD, but no consent of the same was taken from the GNCTD. Further, no correspondence regarding acquisition of 4.03 hectare land was available. Normally, Non-Fare Box Revenue[33] of a Mass Rapid Transit System is in the range of 10 *per cent* of the Fare Box Revenue, but DMRC estimated Non-Fare Box Revenue of 126 *per cent* to 296 *per cent* of Fare Box Revenue from the period 2014 to 2046-47 to make this corridor viable.

Hence, DMRC had not ensured availability of land for Property Development till December 2020 despite the DPR highlighting this as the only way to make the corridor viable.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that when the DPR for the section was prepared in 2007-08, the estimated cost of 4.03 hectare private land was ₹80.60 crore. But when the project was approved in 2012, there was substantial development along the alignment raising the estimated cost to more than ₹1,000 crore making it impossible to acquire the identified plot. DMRC expressed their inability to acquire the identified land till date due to various impediments and the anticipated Non-Fare Box Revenue considered at the DPR stage could not materialise.

The Ministry/ GNCTD/ DMRC did not furnish specific reply to the Audit query on projection of unrealistic assumption of Non-Fare Box Revenue in DPR to make it viable. Thus, the fact remained that assessed revenue of ₹5,178 crore could not be realised in the absence of land required for envisaged Property Development.

(ii) Execution of unviable Mundka-Bahadurgarh corridor

As per the DPR, the proposed metro corridor of Mundka-Bahadurgarh was not financially viable. To make it viable, four hectare of land with 'residential' land use near Ghevra crossing (Delhi) was required for Property Development. As on March 2020, the said land had not been acquired for Property Development, although this was the determining parameter to make the project viable. Audit observed that the identified four hectare land was already planned for establishment of Public Health University and was under litigation since June 2008. However, DMRC did not carry out due diligence at the time of preparation of DPR to ensure availability of land at the approval stage. Rather, DMRC estimated upfront money of ₹168 crore from this four hectare land in the DPR. However, assessed revenue in Delhi portion could not be realised in the absence of envisaged Property Development area. As per the sanction letter (September 2012), it was also stipulated that in case the estimated Property Development revenue of ₹168 crore is not generated, the GoI and the GNCTD have to

[33] ***Non-Fare Box Revenue comprising of revenue from lease out of commercial space, advertisements, consultancy work etc.***

contribute the same as equity to DMRC. However, DMRC did not approach the GoI and the GNCTD for providing the additional equity in lieu of land for Property Development in Delhi portion.

Further, the DPR stated that Government of Haryana (GoH) will provide 1.56 hectare land for Property Development in Haryana portion. While as per the sanction letter, GoH was to provide 10 hectare of land for depot with some element of Property Development, GoH provided 12 hectare land for depot including Property Development. Audit observed that the depot has been constructed and only 0.8 hectare space was available for Property Development, which also remained unutilised as of March 2020. Thus, DMRC has not executed any Property Development activity even in the available 0.8 hectare of land after lapse of seven years from the sanctioning of the project though ₹549.27 crore (during horizon period of 30 years) was estimated from this 1.56 hectare land for estimating Financial Internal Rate of Return.

The Financial Internal Rate of Return was calculated after considering the Property Development income from 4 hectare land in Delhi portion and 1.56 hectare land in Haryana portion.

Thus, DMRC recommended two financially unviable corridors after considering revenue from Property Development without ensuring the availability of required land.

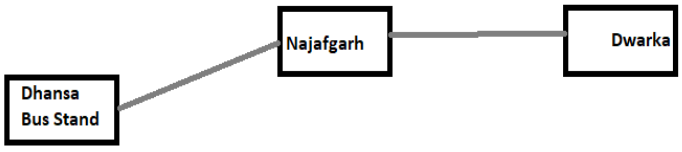
The Ministry and DMRC replied (January 2021 and July 2020) that the GNCTD has not provided four hectare land at Ghevra as proposed in the DPR. Necessary action to develop the remaining 0.8 hectare land (Haryana portion) has since been taken. The Ministry/ GNCTD while accepting (January 2021) the Audit observation for additional equity of ₹168 crore stated that the GNCTD does not have any land, and the required land is to be provided by the Delhi Development Authority (DDA). Accordingly, DDA has been requested to provide funds in lieu of the lands for Property Development. GNCTD endorsed the reply of DMRC.

The reply of the Ministry/ GNCTD and DMRC is not acceptable as DMRC had not ensured availability of said land for Property Development which was of paramount importance to make the project viable.

(iii) Extension of unviable Najafgarh-Dwarka corridor upto Dhansa Bus Stand

DMRC prepared (December 2014) Feasibility Report for Najafgarh-Dhansa Bus Stand (1.18 km length) which was an extension of the Line-9 and had one underground station at Dhansa Bus Stand.

Figure 2.1



The MoUD sanctioned (09 May 2017) Najafgarh-Dhansa Bus Stand section with an estimated completion cost of ₹565 crore. Audit observed that Dwarka-Najafgarh corridor was viable only if the private land for Property Development (4.03 hectare) near Najafgarh station was made available to DMRC.

Since the land could not be acquired, further extension of this unviable Dwarka-Najafgarh corridor up to Dhansa Bus Stand without any Property Development will further increase net cash outflow as construction cost (two times) and O&M cost (10 times) of underground section is much higher than elevated section.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that due to time gap and substantial development, it was not possible to acquire the identified land. Further, while preparing the Feasibility Report for Dhansa Bus Stand extension, fare structure escalation of 7.5 *per cent per annum* and average lead of 16 km was considered for calculation of Financial Internal Rate of Return. This led to positive value of Financial Internal Rate of Return (3.4 *per cent*) even without Property Development land.

The reply of the Ministry/ GNCTD/ DMRC is not acceptable as without Property Development activities on four hectare land, the net cash flow of Dwarka-Najafgarh corridor was negative to the extent of ₹5,178 crore and extending this line to Dhansa Bus Stand will further add to negative cash flows. Also, for an extension of 1.18 km section, fare of average lead/ journey of 16 km had been considered for calculating Financial Internal Rate of Return, which was already considered in earlier extension (Dwarka-Najafgarh). This has resulted in estimation of higher Fare Box Revenue for 1.18 km of Najafgarh-Dhansa Bus Stand.

2.2.4 Non-approval and implementation of Corporate Plan of DMRC

In August 2009, DMRC proposed to revisit its original vision, mission etc., and to prepare a long-term Corporate Plan. Accordingly, consultancy work of revisiting the vision, mission etc., and preparation of a Corporate Plan was awarded (January 2010) to M/s Feedback Ventures with scheduled completion period of 100 calendar days. The consultant submitted its report in 2017-18 and was paid an amount of ₹0.32 crore by DMRC. Audit observed that the horizon period of the proposed Corporate Plan was 2011 to 2021. Thus, a significant period of nine years of the horizon period had already elapsed by the time the Corporate Plan was submitted. The delay was attributed to extension of time given by DMRC due to delay in completion of Phase-II of MRTS and subsequent discussions and presentations to DMRC. The Corporate Plan was approved neither by the Managing Director nor by the Board of DMRC. Thus, even after a lapse of 10 years, DMRC did not have a formal and approved Corporate Plan for guidance towards effective and efficient achievement of its targets and goals.

During Exit Conference (January 2021), the Ministry/ DMRC has agreed for submitting the Corporate Plan to Board of Directors for approval. As horizon period of the said Corporate Plan was upto 2021, a revised Corporate Plan for next horizon period may be prepared and approval of Board of Directors obtained before its implementation.

2.2.5 Change of planning from nine cars to six cars train platform after approval of Phase-III DPR

As per Phase-III DPR, the length of elevated stations was 210 meter and 280 meter to 320 meter in case of underground stations. The Managing Director, DMRC while

discussing (27 May 2011) the change of planning of running nine cars to six cars pointed out that savings in the cost of underground stations for Line-7 and Line-8 shall be the same as given in DPR for Central Secretariat-Kashmiri Gate[34], which was built for six cars trains. For elevated stations, savings was expected to be ₹2 crore for each station. The Managing Director, DMRC pointed out that Peak Hour Peak Direction Traffic of Phase-III as projected in the DPR can be carried by six car trains even up to 2031. Additional Peak Hour Peak Direction Traffic beyond 2031, if any, can be catered to by reducing the train's headway[35], which will be feasible under the Communication Based Train Control system. Accordingly, it was decided that Line-7 and Line-8 should have six car trains instead of nine cars as proposed in DPR. In this regard, Audit observed that:

(i) Due to the decision to change the planning for running nine cars to six cars train, the length of the platform size had to be reduced to 140 meter. Resultantly, the length of the tunnel (in underground) and viaduct (on elevated) also increased. As per the DPR, the cost of tunnelling per km and elevated viaduct was ₹144.31 crore and ₹29.87 crore, respectively. Due to change of decision from nine cars to six cars train operations, there was additional cost of ₹6.49 crore and ₹2.09 crore per station in case of underground and elevated stations, respectively. Thus, DMRC had to incur an additional expenditure of ₹211.53 crore[36]. While the total estimated savings by DMRC due to change of running nine cars to six cars train was ₹234.54 crore, the actual saving was ₹23.01 crore only for Lines-7 and Line-8.

(ii) The design life of the station building is 120 years. In Phase-I & Phase-II, the platforms were designed for eight car trains. Initially train operations were started with four car trains which was increased to eight cars to cater to the increased ridership. However, the reduction in size of platform to six car trains only (in Line-7 & Line-8) has eliminated the possibility and scope for further increase in cars in a rake to cater to the increase in ridership in the future.

(iii) DMRC also decided (27 May 2011) that the saving in civil cost of underground stations for Line-7 and Line-8 shall be the same as given in the DPR for Central Secretariat-Kashmiri Gate. DMRC adopted the estimated cost of underground station building of Line-6 (₹113.01 crore) for Line-8. However, it was observed that width of the Rolling Stock was different in the two lines: in Line-6, type 'A' Rolling Stock of 2.9 meter was used, while in Line-7 and Line-8, type 'B' Rolling Stock of 3.2 meter was proposed. Further, the operations on Line-6 and Line-8 were not similar. Thus, the specifications of both the corridors being different, the cost was not comparable.

(iv) The decision of running six cars train operations instead of nine cars was taken without any cost benefit analysis. Further, no reasons for the reduction were recorded at the time of approval. The decision was neither apprised to the Board of DMRC nor

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[34] ***This was the only corridor having six cars train operations in initial Phase-III DPR***
[35] ***The distance between two metro trains in a transit system measured in time or distance***
[36] ***(₹6.49 crore x 21 underground station) + (₹2.09 crore x 36 elevated station) = ₹211.53 crore***

to the Administrative Ministry. Since the decision of changing of running nine cars to six cars was taken (May 2011) before the sanction letter (26 September 2011) issued by the MoHUA, the Phase-III DPR should have been revised accordingly.

Thus, DMRC changed the train operation from nine cars to six cars without detailed justification, after sanctioning of Phase-III projects. This has resulted in elimination of scope of further expansion to cater to the increased ridership in future.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that the overall saving due to this change was ₹53.25 crore. The decision to reduce the platform station length from nine coaches to six coaches was taken after due deliberation as being advantageous on technical and financial grounds. For underground stations of Line-6, design for coach-width is 2.9 meter whereas for Line-7 and Line-8 the underground stations were designed for the coach width of 3.2 meter. Accordingly, cost of station has been considered in the DPR and no change in other cost like Viaduct/ Tunnel was considered. Since the DPR was submitted in February 2011, while decision was taken in May 2011, it was already in the advanced stage of approval. Hence, revision of DPR at that stage would have further delayed the approval process. As per Delegation of Powers, Managing Director DMRC has been authorised to take such decisions.

The reply of Ministry/ GNCTD and DMRC is not acceptable as low saving in the civil cost is not justified in view of the fact that six cars platform station box has eliminated the possibility and scope for further increase in cars in train composition in the future. Further, total estimated savings due to change of running nine cars to six cars train was ₹234.54 crore, with actual saving of ₹23.01 crore[37] only and not ₹53.25 crore. There was also inconsistency in the decision making, as in Phase-IV of Delhi MRTS from Aerocity to Tuglakabad corridor, nine cars operation was proposed in the DPR though the ridership was less than that of Line-7 and Line-8 of Phase-III. Additionally, as per the minutes of the 13th Board Meeting (January 1998), any substantive change in the scope of work from DPR should be put up to the Board for approval. However, in this case no such approval of the Board was obtained.

2.2.6 Blockage of funds of ₹106.24 crore due to construction of residential complex under Transit Oriented Development

A Transit Oriented Development is a project that mixes residential and commercial opportunities with the objective of optimising the use of land and maximising access to public transport.

Transportation Chapter-12 of Master Plan of Delhi, 2021 as part of review of Master Plan of Delhi-2021 was notified (14 July 2015) by the MoUD, GoI. This chapter envisages Transit Oriented Development policy and development control norms. Delhi Development Authority (DDA) have formulated and notified (November 2015) draft regulations for operationlisation of Transit Oriented Development policy. DMRC planned (August 2015) construction of a residential block at Okhla NSIC station under Transit Oriented Development policy. In this regard, Audit observed that: -

[37] *₹234.54 crore-₹211.53 crore*

(i) There was no approved and notified Transit Oriented Development regulations as the same were under review (from July 2015) of DDA and MoHUA. However, DMRC constructed the residential project under Transit Oriented Development and incurred a cost of ₹82.54 crore on structure and ₹23.7 crore on land cost. The residential complex has been completed (November 2018), but so far, no dwelling unit has been sold/ leased for generating Non-Fare Box Revenue.

(ii) DMRC has been requesting DDA since November 2018 to grant permission of higher floor area ratio of 1.4 as against the permitted 1.0 for residential block. But DDA has not granted any such permission. Audit noticed that Master Plan of Delhi does not provide for any relaxation in floor area ratio for metro stations. Further, due to non-availability of such permission/ approval from DDA, South Delhi Municipal Corporation (SDMC) has not granted statutory approvals for allotment of residential units. Delhi Fire Services provided (August 2016), no objection to DMRC for construction of the said building. However, fire safety certificate from Delhi Fire Services for the residential complex after its completion has not been obtained by DMRC.

(iii) The Ministry has not allowed construction of residential project by DMRC. Moreover, funds for the residential project were utilised from the Phase-III project. No approval of the Board or the Ministry was obtained for implementation of residential project under Transit Oriented Development.

(iv) Transit Oriented Development norms stipulated that 50 *per cent* dwelling units of size ranging between 32 sqm to 40 sqm and balance 50 *per cent* less than and equal to 65 sqm can be constructed. Total 108 dwelling unit areas ranging from 32 sqm to 50 sqm was approved by the Managing Director, DMRC. However, only 93 dwelling units areas ranging from 42 sqm to 110 sqm were actually constructed. Further, six economic weaker section flats were planned but not constructed by DMRC. In addition, 20 *per cent* of the area of the amalgamated plot was to be designed as green public open space. However, this has not been provided at the residential complex.

Thus, DMRC constructed residential project under Transit Oriented Development policy without approved regulations for the same. This has resulted in blockade of funds of ₹106.24 crore.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that the proposal of development of Transit Oriented Development was in accordance with the mandate given to DMRC by MoUD (March 2009) to explore Property Development options, wherever feasible, as an accepted source of resource mobilisation towards capital cost as well as sustainable operations. Accordingly, a commercial cum residential complex was planned at Okhla NSIC as a mixed-use development. Since Transit Oriented Development regulation by the MoHUA was not notified, the proposal could not be submitted to the local authority. The project under consideration consists of 93 residential units of one and two bed-rooms units, commercial area and public spaces as per Transit Oriented Development norm as notified in July 2015 with 1.4 floor area norm excluding operational area and ground coverage of 30 *per cent* which is

within the Transit Oriented Development norms. The Okhla NSIC project qualifies as a Transit Oriented Development project as per both the policies except that Okhla does not fall under any of the Transit Oriented Development nodes as per the new policy. The number of residential units and their sizes cannot be predicted cent *per cent* before completion of the structure design. While developing the concept design, DMRC anticipated 108 residential units but while making the structural drawings, DMRC were able to construct only 93 residences of various sizes. If the project gets approved as per Transit Oriented Development necessary modification can be done to fulfil the size requirement of the guidelines.

The reply of the Ministry/ GNCTD/ DMRC is not tenable because the guidelines of MoUD does not encourage development of residential project under Property Development. The proposal for approval of connection of water, electricity and occupancy certificate etc., has not been issued by local authority due to non-notification of Transit Oriented Development regulations. DMRC in their reply has accepted that it had initially planned to construct 108 dwelling units but ultimately constructed 93 units only. Further, the residential project at NSIC Okhla does not fall under any of the Transit Oriented Development Nodes approved by DDA. The fact remains that construction of residential project without approved Transit Oriented Development Regulations, resulted in blockage of funds of ₹106.24 crore.

2.2.7 Non-adoption of General Financial Rules for sanction and administrative approval from the appropriate authority and for incurring expenditure

2.2.7.1 Execution of work of ₹2,912.21 crore without administrative approval and expenditure sanction

As per Rule 129 (1) of General Financial Rules (GFR), 2005, no works shall be commenced or liability incurred in connection with it until administrative approval has been obtained from the appropriate authority in each case and sanction to incur expenditure has been obtained from the competent authority. In this regard, Audit observed that the works were started by DMRC in violation of GFR as discussed below:

(i) The work on three corridors i.e., Kalindi Kunj-Botanical Garden, Noida City Centre to Noida Sector-62 and Dilshad Garden to New Bus Adda, Ghaziabad were commenced on the basis of signing of Memorandum of Agreement between DMRC and NOIDA/ Ghaziabad Development Authority, but without obtaining the sanction of the competent authority i.e., MoHUA.

(ii) The work on the Faridabad- Ballabhgarh corridor was commenced even without signing of Memorandum of Agreement between DMRC and Government of Haryana and without the sanction of the competent authority. The same was signed on 04 January 2019 i.e., after Revenue Operation Date on 19 November 2018.

(iii) In the case of Kalindi Kunj-Botanical Garden corridor (Line-8 extension), sanction of Cabinet was granted (20 December 2017) after completion of work and just five days before commissioning of corridor. In the case of Dilshad Garden-New Bus

Adda, sanction order was issued (14 February 2019) by GoI with stipulated scheduled completion date as 31 January 2019 (14 days before the issue of sanction order).

(iv) An expenditure of ₹1,081.85 crore, ₹537.68 crore, ₹1,081.72 crore and ₹210.96 crore for Noida City Centre to Noida Sector-62, Kalindi Kunj- Botanical Garden, Dilshad Garden to New Bus Adda, and Faridabad-Ballabhgarh corridors, respectively, was incurred even before sanction/ administrative approval from the competent authority in contravention of the GFR.

Thus, work of three corridors was started without approval of Administrative Ministry and in case of Ballabhgarh extension, DMRC neither signed the MoU with Government of Haryana nor got the project sanctioned from GoI before commencement of work.

DMRC replied (July 2020) that while ordering the work, it was for the State Government to ensure that relevant approvals have been obtained to undertake the work and to get the project sanctioned from GoI. DMRC started the work on getting part money in advance from the State Government. Any delay in getting the sanction by GoI is the responsibility of the Government of Uttar Pradesh (GoUP). However, GoUP had signed the MoU before the project was sanctioned by GoI. Therefore, there is no violation of GFR. The Ministry/ GNCTD replied (January 2021) that these corridors were taken up after signing of Agreement with the respective authorities and release of fund by them. Procuring administrative approval and expenditure sanction was the responsibility of the concerned authorities and the same were obtained before commissioning of the lines.

The reply of DMRC is not acceptable as the work on these NCR extensions was commenced without the approval of the MoHUA and GNCTD. Commencement of work without approval of the competent authority is violation of GFR provisions. In 2012, at the time of drafting Memorandum of Agreement for Phase-III, MoUD instructed not to assign any other work to DMRC without prior consent of MoUD. However, the consent/ approval of the same from GoI was not taken before commencement of work. Being a Government organisation, DMRC has to abide by the procedure for construction of any metro corridor. Hence, it is also the responsibility of DMRC to ensure that all obligations have been fulfilled before commencement of any construction work.

2.2.7.2 Additional estimated expenditure of ₹3,246.80 crore relating to modification/ change in alignment of already sanctioned Phase-III corridors without approval of Cabinet

As per Rule 131 of GFR, 2005, any anticipated or actual savings from a sanctioned estimate for a definite project, shall not, without special authority, be applied to carry out additional work not contemplated in the original project.

Phase-III Delhi MRTS project was sanctioned and funded by the GoI and the GNCTD, and any modification/ deviation in sanctioned project/ corridor having financial implications require approval of sanctioning authority as per GFR provisions. Further, MoUD vide its letters dated 18 December 2012/ 31 October 2014, directed that any

deviation in Phase-III projects and extensions as against approved DPR would require Cabinet sanction with details/ justifications. In this regard, Audit observed that:

(i) Managing Director, DMRC modified (December 2011) the elevated alignment between Janak Puri (West) to Palam into underground section as a result of which the number of stations got reduced from four to three just after three months from sanctioning (September 2011) of the project by the GoI due to infirmities in the DPR. This change in alignment from elevated to underground led to additional cost of ₹601 crore which was to be met from the savings in the project. Besides, five other sections were also modified.

(ii) DMRC, in its midterm appraisal (2013) on Phase-III MRTS corridors had apprised the Board that there was marginal increase of ₹106 crore (0.26 *per cent*) over the sanctioned cost. It also apprised to the Board that there was an increase of 13.30 km length in the underground section and decrease of 11.214 km length in the elevated section. Based on estimated completion cost for the underground section and elevated section for Phase-III as per DMRC letter dated 08 April 2011, Audit calculated the additional estimated cost of these modification in alignment as ₹3,246.80 crore[38], which was 8.58 *per cent* (₹3,246.80 crore/ ₹37801.61 crore) of the sanctioned cost of initial phase-III corridors and Dwarka-Najafgarh. Moreover, for increase in completion cost vis-à-vis sanctioned cost, approval of the Cabinet was not sought.

(iii) Utilisation of saving from already sanctioned projects without the approval of the competent authority i.e., the Administrative Ministry (MoHUA) as per GFR was not prudent.

Thus, DMRC modified the alignments after sanctioning of the corridors by the GoI and approval was not obtained from GoI. Further, DMRC incurred expenditure of ₹3,246.80 crore after utilising the saving of already sanctioned Phase-III corridors in contravention of GFR provision.

DMRC replied (July 2020) that the cost of change in alignment from elevated to underground was to be met from the expected saving of Phase-III. Hence, the case was not sent to the MoUD. As per the preliminary expenditure details, the total expenditure for Phase-III is ₹42,734 crore (approx.) against the DPR provision of ₹39,796 crore. Further, out of ₹2,938 crore i.e., extra expenditure over and above the sanctioned cost, only ₹525 crore (1.47 *per cent*) was on account of actual construction of Civil, Electrical and Mechanical, Traction, Signalling and Telecom and Rolling Stock. The remaining expenditure was mainly on account of delay in handing over of land by various agencies and consequent extension of period of Phase-III. The completion cost as mentioned is the DPR cost and not the actual completion cost of Phase-III. Therefore, additional cost worked out by Audit was not correct, as it does not include savings obtained in contracts.

The Ministry/ GNCTD replied (January 2021) that Empowered Group of Ministers vide meeting held on 4 August 2000 directed that changes of design/ technical nature

[38] ***₹3,246.80 crore = {13.29 x ₹408 crore} – {11.214x ₹194 crore}***

vis-à-vis the DPR should be settled by DMRC Board unless these involve significant cost and time overruns or have major implications of such a nature as cannot be considered to be internal to the project. These changes are purely due to technical reasons internal to the project. The excess cost on this account was contemplated to be adjusted from the expected saving of Phase-III. Thus, the approval of these modifications was within the power of DMRC Board of Directors whose approval was taken by DMRC.

DMRC accepted that ₹2,938 crore was the extra expenditure incurred over and above the sanctioned cost. Hence, approval of both utilisation of funds from savings of sanctioned funds and incurring of additional expenditure should have been obtained from GoI. Further, break up (line wise and item wise) of expenditure of ₹42,734 crore against the DPR provision of ₹39,796 crore has not been provided to Audit despite requisition[39] and repeated reminders. The details of actual savings made in contracts has also not been furnished to Audit. The reply of the Ministry is not acceptable as modifications from elevated section to underground section involve significant cost overrun (i.e., 2 times) and time over run (i.e., 6 months to12 months). Further, MoUD letters issued in December 2012 and October 2014 also require approval of Cabinet for any deviation in Phase-III projects and extensions as against approved DPR.

2.3 Selection of Technology

A metro system requires a complex set of technological infrastructures and components to ensure its smooth operations. These components include Rolling Stock, Signalling system, Electrical, Track and Traction System etc. DMRC's planning and execution of various technologies in various lines of the metro system were examined by Audit along with the Technical Consultant (IIT Delhi) and the observations are as brought out in the following paragraphs.

2.3.1 Rolling Stock

During Phase-III, DMRC procured 924 metro cars at a cost of ₹7,862.71 crore through four contracts which include three contracts (RS-9, RS-11 and RS-13) for augmentation of Rolling Stock in existing Line-1 to Line-6 and a contract (RS-10) for newly constructed Lines-7, 8 and 9 as detailed below:

Table 2.1
Details of Rolling Stock contracts executed during Phase-III

Name of the contract	Procured for Line	Name of the contractor	Date of award of Contract	No. of cars procured	Awarded cost of one car (₹ in crore)
RS-9	5 & 6	M/s BEML & Hyundai Rotem consortium (BR Consortium)	01.07.2013	92+70= 162	8.22

[39] *vide Audit Requisition no. 92 in December 2019*

Name of the contract	Procured for Line	Name of the contractor	Date of award of Contract	No. of cars procured	Awarded cost of one car (₹ in crore)
RS-10	7, 8 & 9	M/s Hyundai Rotem Company	01.04.2013	486+18= 504	8.62
RS-11	2, 3 & 4	M/s Bombardier Transportation India Private Ltd	12.06.2015	124+38= 162	9.25
RS-13	1, 2, 3 & 4	M/s BEML Ltd	21.05.2015	74+22=96	8.82
Total cars				**924**	

In this regard, Audit observed the following:

2.3.1.1 Inconsistency in variation clauses of Rolling Stock contracts

DMRC awarded four contracts[40] for procurement of Rolling Stock during the implementation of Phase-III. The variation clause in the contract agreements except RS-9 stipulates that the employer at his discretion may advise the contractor in writing about increase of the total quantity up to 30 *per cent* of the tendered quantity. However, the variation clause of RS-9 contract stipulates the variation quantity up to 60 cars (65 *per cent*) of the tendered quantity of 92 cars. The quantity was augmented up to 70 cars (76 *per cent* of tendered quantity) through a variation order.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that there is no stated guideline for quantity variation option to be followed in all contracts and the variation quantity is worked out based on anticipated requirement of additional quantity in the near future and included in the tender so that the additional quantity can be procured at the contracted terms without going through the process of fresh tendering.

It is suggested that as DMRC deals with significant number of contracts in metro projects, they should have a stated guideline for quantity variation in order to maintain consistency.

2.3.1.2 Avoidable expenditure of ₹3.24 crore due to non-incorporation of rate of Heating Ventilation and Air Conditioning Coefficient of Performance in RS-11 contract

Employer's Requirements Technical Specification (ERTS) of Heating Ventilation and Air-Conditioning under RS-11 contract stipulates that employer expects that energy efficient system comparable with the best available in the market shall be provided. However, in contract RS-13 under ERTS, it was mentioned that Coefficient of Performance[41] of Heating Ventilation and Air Conditioning shall not be less than 2.5 in summer and monsoon season under both outdoor and indoor conditions. DMRC initiated the tendering process of both RS-11 and RS-13 contracts in 2014. Hence, there

[40] ***RS-9, RS-10, RS-11 and RS-13***

[41] ***Coefficient of Performance indicate the ratio of heating or cooling provided by a unit relative to the amount of electrical input required to generate it. Higher Coefficient of Performance equate to higher efficiency, lower energy (power) consumption and thus lower operating cost***

was no reason for the clauses of Heating Ventilation and Air Conditioning Coefficient of Performance to be different in the two agreements.

Further, instead of approving the Heating Ventilation and Air Conditioning Coefficient of Performance of 2.5 (as in the case of RS-13 which was comparable with the best available) without any extra expenditure, DMRC granted variation of ₹3.24 crore (November 2017) to the contractor for Heating Ventilation and Air Conditioning Coefficient of Performance 2.3 in RS-11, which was a lower version than RS-13. Besides, the awarded cost[42] of RS-13 with Coefficient of Performance of 2.5 is less than RS-11. If RS-11 having Heating Ventilation and Air Conditioning with Coefficient of Performance 2.3 would have been purchased without variation and consistent clauses were incorporated in the tenders, DMRC could have saved up to ₹3.24 crore.

Thus, DMRC procured less efficient Heating Ventilation and Air Conditioning system in RS-11 contract after incurring additional expenditure of ₹3.24 crore.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that Notice Inviting Tender of RS-11 (augmentation of RS-2/ 5/ 7) and RS-13 were floated on 22 July 2014 and 22 August 2014, respectively. During the design evaluation phase (October 2015), it was noticed that Coefficient of Performance was as low as 1.7. DMRC informed M/s Bombardier Transportation (contractor) to improve Coefficient of Performance to the level of 2.5. The contractor informed (May 2016) that improved Heating Ventilation and Air Conditioning with Coefficient of Performance 2.3 is developed by the Original Equipment Manufacturer and mentioned that additional time and cost would be required for this additional work. Based on the mainline tests, total saving of energy per Heating Ventilation and Air Conditioning per hour works out to be 7.35 units. Considering energy cost of ₹6.03 per unit and 12 hours of operation daily, saving per day works out to be ₹532.36 per system. Considering the same, the variation cost will get paid back to DMRC through energy savings in approximately 175 days (approximately six summer months).

The reply of the Ministry/ GNCTD/ DMRC is not acceptable as it is silent on the Audit observation regarding non-incorporation of the rate of Heating Ventilation and Air Conditioning Coefficient of Performance in RS-11 contract as mentioned in RS-13 contract although approval for procurement of RS-11 and RS-13 was taken at the same time in June 2014. In this regard, Audit observed that a highest possible value of Coefficient of Performance of Heating Ventilation and Air Conditioning (keeping up with industry state of art) may be specified in the contract instead of comparing to later variations, which might be difficult or have cost implications at a later stage. DMRC is justifying the variation amount paid on the basis of saving in energy. Further, incorporation of the clause for Coefficient of Performance 2.5 energy efficient Heating Ventilation and Air Conditioning, would have resulted in continuous saving of energy in the future years without any variation.

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[42] ***Awarded cost of RS-11 Rolling Stock: ₹9.25 crore per car, RS-13 Rolling Stock: ₹8.83 crore per car***

2.3.1.3 Introduction of Unattended Train Operation technology without preparedness and cost-benefit analysis

DMRC issued (03 March 2012) Notice Inviting Tender (NIT) on International Competitive Bidding basis for 486 standard gauge cars (RS-10). Meanwhile, a detailed note was submitted (29 May 2012) to the Managing Director, DMRC by three Directors of DMRC stating that DPR of Phase-III corridors envisages train control and signalling system based on Communication Based Train Control which is an excellent opportunity for introduction of Unattended Train Operation[43] feature with marginal cost and attendant benefits. The note was approved (31 May 2012) by the Managing Director, DMRC. The benefits would include saving in manpower in depot and, to a certain extent, in the main Line too. In case of RS-10 contract, a clause related to minimum Guaranteed Energy Consumption during one round trip of Line-7 (factory test and actual Line) was included. In case of non-achievement of Guaranteed Energy Consumption, penalty was to be levied according to the penalty clause as mentioned in the contract.

In this regard, Audit observed that:

(i) During the preparation and approval stage of DPR of Phase-III (2008-11), proposal for introduction of new technology i.e., Unattended Train Operation along with proposed benefits/ merits were neither discussed nor appraised by DMRC at any stage before May 2012.

(ii) Although the mode of operation of Rolling Stock was modified, DMRC did not revise the estimated cost considering Unattended Train Operation mode and their features like additional Closed Circuit Television etc., in NIT.

(iii) Since DPR was prepared based on normal Rolling Stock, there was no provision for Platform Screen Doors in the DPR for Phase-III lines. Later, due to shifting at Unattended Train Operation mode, DMRC had to award the supply and installation of Platform Screen Doors contract for Line-7 and Line-8 at ₹312 crore.

(iv) At approval stage, DMRC stated that after introduction of Unattended Train Operation there would be cost reduction as number of Train Operators would be reduced. Yet, no cost benefit analysis was made by DMRC' and moreover in many countries Unattended Train Operation with staff/ driver was in operation for a long time. Thus, claim of DMRC regarding cost cut due to reduction/ rationalisation in number of Train Operators after the introduction of Unattended Train Operation is doubtful.

(v) Rolling Stock (RS-10) was operational since 25 December 2017 and due to lack of connectivity of Line-7, DMRC had not conducted Guaranteed Energy Consumption test online. Hence, any achievement of Guaranteed Energy Consumption value in real conditions by the contractor, and penalty, if any, in case of non-achievement of Guaranteed Energy Consumption could not be ascertained (31 March 2021).

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[43] ***Unattended Train Operation is level of automation (GoA4), wherein the train shall be operated without train operator. Operation Control Centre will send a command to ATC system onboard to operate the train so as to align train doors with the Platform Screen Doors.***

Thus, DMRC introduced Unattended Train Operation technology without mentioning the same in DPR and also cost benefit analysis was not conducted at the approval stage.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that Communication Based Train Control technology had reached its maturity. Further, features required for operation in GoA3[44]/ GoA4[45] could be incorporated in the new Rolling Stock and Signalling and Train Control System at incremental additional cost but within the provisions available in the DPR of Phase-III, and that if these features were incorporated at a later date, the cost would be very high. As Unattended Train Operation with Communication Based Train Control was already a rapidly evolving and preferred technology for a number of metro systems, no major cost implications were envisaged and thus the estimate was not revised. The cost cut due to reduction of numbers of Train Operators can be ascertained only after introduction of Unattended Train Operation. DMRC agreed that initially, Platform Screen Doors were not considered. However, although not essential, under Indian conditions with Unattended Train Operation provision, Platform Screen Doors is expected to increase passenger safety against accidental falls and unauthorised entry to track. The demonstration on mainline is pending as the specified section from Mukundpur (Majlis Park) to Maujpur is still not ready due to pending construction work.

The reply of the Ministry/ GNCTD/ DMRC is not acceptable as introduction of new technology was neither discussed nor appraised by DMRC at any stage before May 2012. DMRC admitted that no cost estimation was made before introduction of Unattended Train Operation. Further, Audit has not been provided any component wise cost of Rolling Stock, either actual or estimated. Estimates are prepared on lump sum basis and to say that Unattended Train Operation functionality involves only marginal cost, is unverifiable. Further, Platform Screen Doors is an essential feature[46] for Unattended Train Operation System. In Phase-I, out of three Lines executed during Phase-I, Automatic Train Operation was introduced on only Line-2. Later, the same was introduced on all new Lines of Phase-II i.e., Line-5 and Line-6, whereas, Unattended Train Operation was introduced in all new lines of Phase-III (Line-7, Line-8 and Line-9) without any prior experience.

2.3.1.4 Excess procurement of Rolling Stock in Phase-III resulting in its idling

DMRC awarded four contracts for the procurement of Rolling Stock during Phase-III. Three of them viz. contract RS-9, RS-11 and RS-13 were awarded to meet the procurement of 420 metro cars of existing lines (Line-1 to Line-6) and extension of

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[44] ***Grade/level of automation wherein fully automated train operation but train driver will remain in cab for attending emergency situations***

[45] ***Grade/level of automation wherein fully automated train operation without driver in cab. In case of emergency situation, the same is handled by the operation control centre staff***

[46] ***In response to Board of Directors observation (91st meeting) on installation of Platform Screen Doors, Director (Operation) stated that Platform Screen Doors are becoming necessity in case of manual train operation also. Further, in response to Audit observation mentioned in para 3.11, DMRC stated that use of Platform Screen Doors is mandatory with Unattended Train Operation.***

existing lines during Phase-III. RS-10 contract was awarded for procurement of 504 metro cars for Line-7, Line-8 and Line-9.

Audit observed that DMRC estimated the requirement of Rolling Stock in the DPR prepared in February 2011, whereas the procurement was initiated in 2013-14. At the time of tendering, DMRC did not conduct any analysis for the projections of requirement of Rolling Stock on the basis of actual turnaround time of each line, actual length of metro line, actual speed of Rolling Stock (Automatic Train Protection, Automatic Train Operation, Unattended Train Operation mode), reserve stock criteria, and Peak Hour Peak Direction Traffic. Considering actual parameters i.e., actual operational plan, actual speed of Rolling Stock, actual reversal time on the lines, Audit had worked out (by using formula of DMRC for procurement of RS) that DMRC had procured 84 excess metro cars during Phase-III amounting to ₹739.20 crore.

Technical Consultant (IIT Delhi) stated that no mathematical/ scientific model was found to justify the excess purchase of Rolling Stock in Phase-III. DMRC's stand that it was done on the basis of their experience, appears to be unjustified. Thus, DMRC should consider a scientific model like "Rolling Stock Circulation Model for Railway Rapid Transit Systems" for procurement of metro cars.

Thus, DMRC did not analyse the requirement of Rolling Stock on the basis of actual parameters at the time of procurement. This has resulted in excess procurement of Rolling Stock and its idling.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that DPR is the only available document to determine Rolling Stock requirement. For factors like turnaround time, length of Line, speed of Rolling Stock, there is rarely any change from DPR provisions. The train operation plan had taken into consideration all these factors while assessing the requirement of cars. Traffic forecast considers several factors into account. All these assumptions may not materialise in the expected way. Further, the percentage of unutilised cars depends on several factors. The trains on Line-7 are not being operated fully owing to discontinuity at Trilokpuri due to Rehabilitation and Resettlement issue.

The Ministry/ GNCTD/ DMRC reply is not acceptable as the operational plan determined in the DPR differs from the actual operational plan. Hence, DMRC should have analysed the requirement of Rolling Stock on the basis of actual operational plan, turnaround facility available at terminal metro station, actual length of metro corridor, speed of Rolling Stock i.e., Automatic Train Protection, Automatic Train Operation, actual increase in ridership and Peak Hour Peak Direction Traffic during the period as Audit noticed inconsistencies in these parameters from DPR provisions. The contention of DMRC regarding partial operation of Line-7 is not tenable as the same headway (frequency), as mentioned in DPR, has been maintained.

2.3.1.5 Deficiencies in the Rolling Stock and Rail

(A) Quality issues of rails and wheel of Rolling Stock

(i) Hardness measurement (at site/ depot and laboratory) were conducted by the Technical Consultant (IIT Delhi) along with Audit Team the in the presence of DMRC team on Line-7 (IP extension metro station, Vinod Nagar Depot and Mukundpur Depot) which revealed that both the rails (NHH[47]-880 and HH[48]-1080) possess relatively low values of hardness as compared to the values as per set standards. As per Indian Railway Standard Specification (December 2009) and as per DMRC specifications, the hardness value of rail should not be less than 260 BHN[49] for HH 880 rail head (Depot area) and hardness value should be in the range of 340-390 BHN for HH 1080 (main Line). However, actual hardness values measured were in the range of 217-292 BHN (Depot area) and 260-360 BHN (main Line). This indicates that DMRC has used rails of relatively less hardness. This may result in increased maintenance cost for DMRC due to decreased life of rails and wheels.

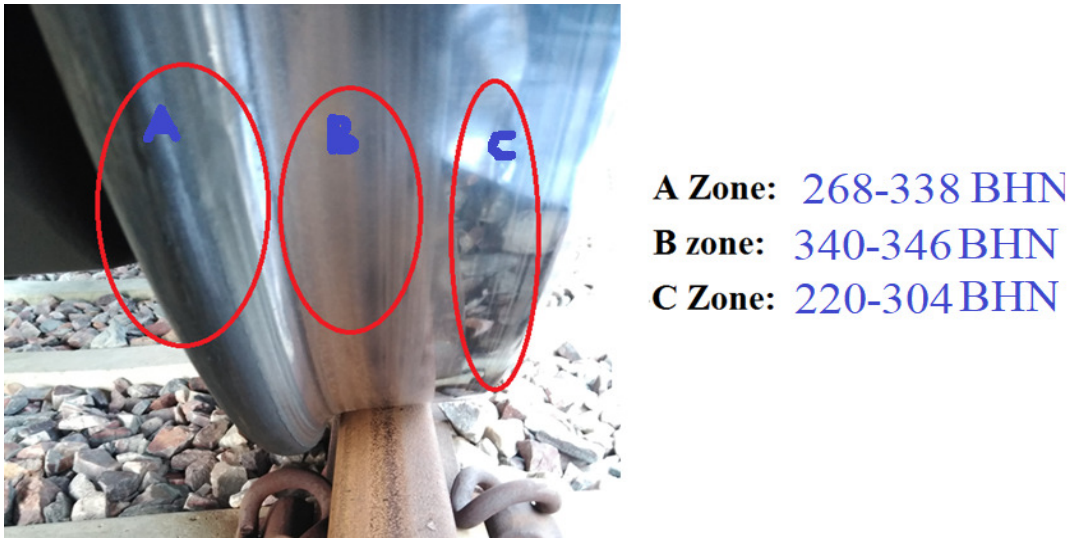
Figure 2.2
Measuring of rail surface hardness of Line-7 (IP extension metro station on 31 January 2020)

[47] ***Non-Head Harden***
[48] ***Head Harden***
[49] ***Brinell Hardness Number (BHN)- The Brinell hardness test is commonly used to determine the hardness of materials like metals and alloys***

(ii) DMRC stated that hardness of rail should be more than wheels, as through passes of runs, will lead to the wear and tear of wheels and rail, and replacing the worn rails would be easier than replacing the wheels. During on-site investigation, it was found that hardness of wheels (at the locations which contact rail) and rails were almost the same, which is good for longer wheel life. Keeping this in mind (i.e., increase in hardness at the contacts due to strain hardening during run), DMRC should have used rail and wheels with equal hardness (or may be even more) from the beginning itself in order to have good performance from running-in periods.

Figure 2.3

Photographic view of a wheel's surface hardness in three zones (A, B, and C) measured in presence of DMRC (Vinod Nagar depot on 31 January 2020)



(iii) DMRC sends wheels for grinding/ turning after they have run for some kilometres. It was observed that the decision on grinding/ turning of wheels should be taken after considering the permissible increase in noise and vibrations as well. After grinding/ turning, the harden layer of the wheel is removed with increased surface roughness. In such a case, DMRC did not have any technical means to increase the hardness of wheels and to improve the surface finish of the wheels and rails. Restoring the hardness on flanges of the wheels and rails (after grinding) is paramount as increase in vibration and noise was recorded after turning and grinding of wheels and rails, respectively.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that DMRC procures Rails and Wheels according to International Standards. Wheel profiling is measured as per the parameter provided by Original Equipment Manufacturers (OEMs). The Ministry added that DMRC is open to refer to the suggestions made to Rolling Stock manufacturers and Research Designs and Standards Organisation/ Ministry of Railways as no such technical instructions are available as of now.

The Ministry/ GNCTD/ DMRC reply is not acceptable as the rail samples (unused) were collected from DMRC for measurement of hardness in the IIT Delhi laboratory. Measurement of hardness revealed low value of hardness in critical areas. Technical

Consultant (IIT Delhi) observed that the Ministry/ GNCTD/ DMRC's reply regarding grinding and turning of wheels lacks technical explanation. DMRC should integrate the vibration and noise levels while deciding the time for turning the wheel and grinding the rails head. For this vibration and noise inside the car near the side wall and in the vicinity of floor should be picked-up. These two parameters will also reveal the quality (in terms of hardness and wear) of rails and wheels. Hence, DMRC may explore ways to restore the hardness of rails and wheels.

(B) Higher vibration and Noise

As per ISO 2631 norms, passengers should not be subjected to vibration level more than 0.315 meter per second squared (m/s^2). Audit along with the Technical Consultant (IIT Delhi) observed that vibration and noise levels were higher than permissible values at different locations of Line-7 (inside Rolling Stock, noise and vibration tests were conducted from Mayur Vihar Pocket -1 to Majlis Park and vice versa and outside Rolling Stock, noise test was conducted at Sarai Kale Khan and Majlis Park metro station). The vibration level was higher in several places with maximum value up to 2.5 m/s^2. This indicated that interface of wheels and rails was not proper, and the noise/ vibration absorption system needs attention. Exterior noise level was also found exceeding the permissible limit in the range of 69 decibel to 80 decibel.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that the noise and vibration inside and outside of metro trains are measured as per the technical standards (specified in the Contract).

The reply of the Ministry/ GNCTD/ DMRC is not acceptable because if rails have less hardness (as found during the measurements), friction is found to increase at rail and wheel interfaces. Thus, DMRC may regularly review vibrations and noise levels inside and outside the Rolling Stock.

(C) Issue of lubricant waste on the track

Lubrication at the interface of rail and wheel flanges (during negotiating a turn) is achieved by spraying directed lubricant (synthetic chemicals). While the lubricant may be essential for machine contacts, it is hazardous for humans and the environment. Visual inspection of track revealed presence of contaminants at the side of railhead, which is for interfacing with wheel's flanges. Thus, DMRC did not have an integrated system of biodegradable lubrication based on bio-degradable oils.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that during Phase-III oil-based wheel flange lubricator was used which was technically defined as "Readily Biodegradable according to OECD[50] 301B".

The reply of the Ministry/ GNCTD/ DMRC needs to be viewed in the light of the fact that DMRC was unable to provide the FTIR[51] spectra of lubricant for understanding

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[50] ***Organisation for Economic Cooperation and Development***

[51] ***Fourier-transform i.e., used for detecting degradation, dilution, or illegal additives in different types of oils***

whether lubricant used was biodegradable or not. DMRC further noted the suggestions for use of biodegradable oil.

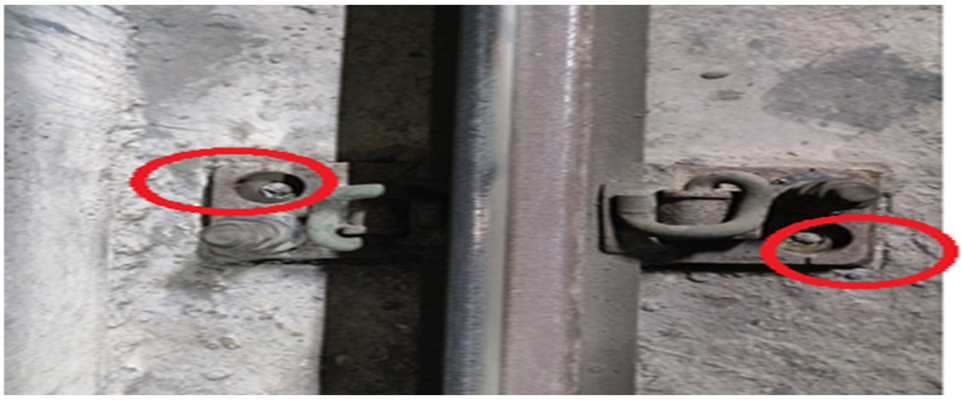
(D) Maintenance issues of Rolling Stock

(i) A visit of tunnel at Hauz-Khas metro station was conducted by Audit along with Technical Consultant (IIT Delhi) for assessing the maintenance aspects of rail track and related matters. It was noticed that there were corrosions of rail, tie plates, nuts and bolts indicating that there was presence of water/ moisture near the track. Hence, DMRC should have ensured prevention of water leakage during maintenance for good rail life.

(ii) For removing the contaminants/ingress from lubricated surface of head, there should be regular process, else lubricant will not be effective at the interface of rail and wheel. This will result in accelerated wear of wheel flange and side of rail head causing increase in the maintenance cost.

(iii) Missing bolts from the plate, besides damage on rail heads were also noticed during site visit, as shown in Figure 2.4.

Figure 2.4
Views of tie plates and bolts
(a) Missing bolts (b) corroded bolts & nuts
(Hauz-Khas station, l8 December 2019)



(a)

(b)

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that O&M wing of DMRC takes all needful action to ensure longer service life of Rails and ensured to take higher level of precautions as recommended. As per RDSO[52] approval, Pandrol fastening system has arrangements for four bolt holes in base plates but provision of two bolts is adequate for Tangent track & curves sharper than 500 meter. DMRC adopted two bolts for the Tangent track and curves sharper than 1,000 meter.

The Ministry/ GNCTD/ DMRC explanation of needful action taken is not convincing because Audit noticed corrosion of rail and contaminants/ ingress from lubricated surface of head on rails during verification and there should be a process for removing the contaminant and ingress. Further, using a plate of four holes in place of two holes and leaving two holes empty may allow moisture/ water and is a source of contamination & storage.

2.4 Signalling system

Signalling system is used to control traffic and to ensure safe operation of trains. The parameters of the system used in the project have been worked out keeping in mind the smaller headway of train operations and consequent safety requirements. In Phase-I and Phase-II, DMRC adopted Distance to Go, Automatic Train Protection, Automatic Train Supervision and Automatic Train Operations to optimise Rolling Stock operations. Detailed Project Report for Phase-III corridors envisaged adoption of Train Control & Signalling System based on Communication Based Train Control technology. This technology offers inherent built-in capability of better two-way communication between train locations on track and train. In this regard, Audit observed the following:

2.4.1 Avoidable expenditure of up to ₹23.97 crore due to deficient tender evaluation

Tenders for train control and signalling system for Line-7 and Line-8 were issued (28 September 2012 to 08 October 2012) by DMRC. The contract package CS 03 and CS 04 are given as under: -

Table 2.2

Tender	Line	Description of Sections	Route km	Number of stations	Estimated cost as per DPR (₹ in crore)	Estimated cost put to tender (₹ in crore)	Awarded cost per/ km (₹ in crore)
CS03	Line-7	Mukundpur-Maujpur-Shiv Vihar	58.59	38	568.69	435.28	6.09
CS04	Line-8	Janak Puri West-Botanical Garden	37.46	25	383.91	290.43	6.73

[52] ***Research Design & Standards Organisation: It is a research and development organisation under the Ministry of Railways of GoI, which functions as a technical advisor and consultant to the Railways Board, RITES, RailTel and IRCON International in respect of design and standardisation of railway equipment and problems related to railway construction, operations and maintenance.***

As per Para A 1.7 of Notice Inviting Tender (NIT), CS 03 and CS 04 may not be awarded to the same tenderer.

In this regard, Audit observed that:

(i) The cost per km for Line-7 and Line-8 was ₹6.09 crore and ₹6.73 crore, respectively. The financial bid of CS 03 was opened (05 June 2013) initially and followed by opening of the financial bid of CS 04 on 15 July 2013. Since the price bid of Line-8 was opened subsequently and DMRC was aware that M/s Bombardier has quoted less, efforts should have been made by DMRC to ask M/s Nippon Signalling to match the price quoted by M/s Bombardier. The price difference was ₹64 lakh per km in CS 03 and CS 04 tender. This may have resulted in a saving of up to ₹23.97 crore (37.46 km x ₹0.64 crore) to DMRC.

(ii) As per NIT, the work of Line-7 and Line-8 may not be awarded to one contractor. Once the lowest eligible tenderer is established for CS 03, the financial bid of CS 04 shall be opened. At this stage, the financial bid of the tenderer who has been established lowest in CS 03, shall not be opened. This condition put by DMRC was restrictive and did not ensure fair competition. Further, in contract CS 03, M/s Bombardier was L1 and M/s Nippon Signalling was L2. Due to restrictive condition put by DMRC, M/s Nippon Signalling who was L2 in CS 03 contract was bound to come L1 in CS 04 contract.

(iii) Calling of separate tenders resulted in two separate and distinct signalling systems for Line-7 & Line-8 for the same Rolling Stock (RS 10). Thus, DMRC has to maintain separate inventory, impart separate training to the personnel, and have separate train control system at the Operation Control Center etc. DMRC had to incur extra cost for inventory as well. Besides, rotating of personnel from one line to another may create operational difficulties due to differential understanding of the signalling systems.

Thus, the condition placed by DMRC was restrictive and did not ensure fair competition. This has resulted in avoidable expenditure of ₹23.97 crore.

The Ministry/ GNCTD and DMRC has accepted (January 2021 and July 2020) the Audit observation and stated that for similar contracts in future, after deciding L1 in the first tender, financial bids of all the bidders in the 2nd tender would be opened. If L1 is the same for both the tenders, then L2 would be asked to counter offer the rates of L1.

2.4.2 Deficiencies in the Communication Based Train Control System

As per the final Report (November 2013) of Sub- Committee on Standardisation of Signalling & Train Control System constituted by MoUD, the Communication Based Train Control System, as defined in the IEEE[53] 1474 standard, is a "continuous automatic train control system utilising high resolution train location determination, independent of track circuits, continuous, high capacity, bidirectional train-to- wayside data communications, and train borne and wayside processors capable of implementing vital functions. Communication Based Train Control system includes the following

[53] *the Institute of Electrical and Electronics Engineers*

subsystems, 1) train onboard system, 2) train-to-trackside radio system, and 3) backbone trackside signalling system. The subsystems work individually and, in case of failure, coordinates with each other without disturbing their operation.

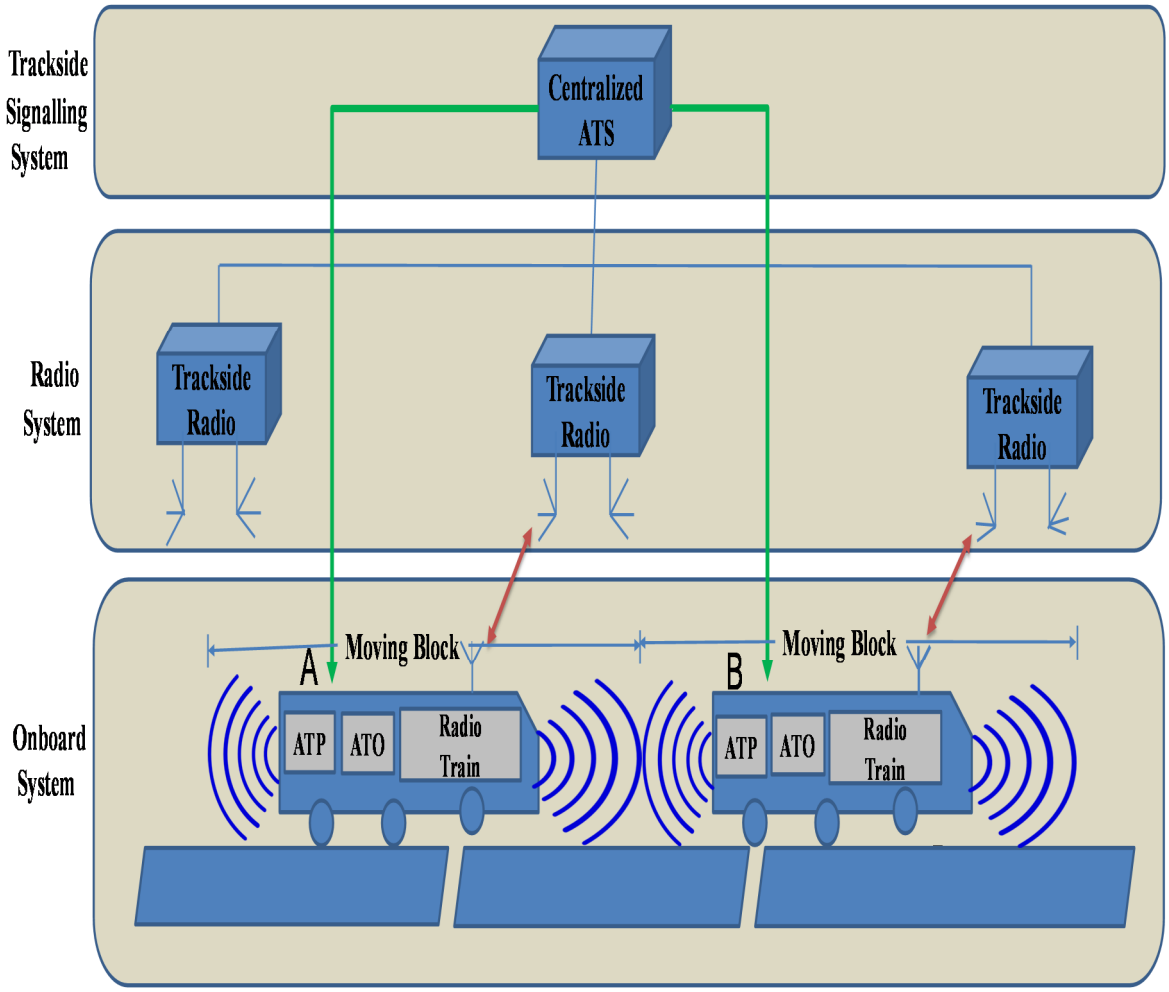
The onboard system contains Automatic Train Protection, which controls safety-related functions and determines movement authority and Automatic Train Operation, which controls the actual train driving functions and can be used to realise driverless operations.

The onboard system detects the train location and sends this information to the trackside signalling system, which further uses this information to form the control pattern (information) sent to each train. The onboard system calculates the control pattern and controls the speed of the train.

The trackside signalling system controls the train headway and controls interlock (route). It contains Automatic Train Supervision responsible for the overall centralised signalling and train operation data. Centralisation of the system improves the availability of the track operation by controlling all functions from a single processing unit.

Figure 2.5

Functional diagram of the Communication Based Train Control system



This technology has been approved by MoHUA and following is observed in this regard.

(i) Reduced reliability due to wireless connections of Access Points of the Communication Based Train Control system

During verification at Line-8, it was observed that Access Points are wirelessly connected inside the tunnels without any redundancy. Due to curvature in the tunnels, the wireless signal from one Access Point reaches another Access Point after getting reflected through multiple paths, resulting in multipath fading (interference from several reflected paths). This may result in severely reduced amplitudes at the receiver, decreasing the reliability of the link. Due to multipath fading, this architecture has a decreased reliability[54], which is a deficiency in planning or designing by DMRC. Thus, proper measurements and tests must be conducted to gain assurance regarding the possibility of fading in such architectures.

In Line-7, the Access Points are connected using optical fibres. The transmission mode of the free wave has the worst anti-interference capability to WiFi signals[55]. Thus, the architecture of the Line-7 has better reliability (due to no fading and low interference susceptibility to WiFi), and consequently, better up-times. However, DMRC did not put this (wired connections of the Access Points) as a requirement in their tender, leading to a less reliable architecture in Line-8.

There are also other noted advantages of using wired connections between the Access Points**,** such as longer link length, as a signal in free space suffers from a higher attenuation. Thus, a higher number of Access Points are typically required in wireless Access Points compared to the Access Points connected through wired infrastructure. During site visit from Hauz Khas metro station to IIT metro station at Line-8, discussion with the metro staff also revealed that the speed of the train is less in the tunnel as compared to viaduct. However, the actual up time data to assess the speed inside tunnels was not provided by DMRC. It is felt that one of the reasons for the speed being curtailed was due to non-installation of adequate number of signalling equipment. Thus, Access Points are wirelessly connected without any redundancy thereby reducing the up-times[56] of the Communication Based Train Control system which would pose reliability concerns in the required up-time.

The Ministry/ GNCTD and DMRC agreed (January 2021 and July 2020) that the system connected using wired cables is more reliable and is cost-effective in principle. However, it felt that only allowing the vendors who supply the system connected using wired connections will make the tender very restrictive.

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[54] ***L. Ming, H. S. Wang, H. Zhao, and L. Zhu, "Test and analysis on the interference to the Communication Based Train Control systems by WiFi signals," International Journal of u-and e-Service, Science and Technology, vol. 8, no. 3, pp. 123-132, 2015***

[55] ***T. Wen, C. Constantinou, L. Chen, Z. Tian, and C. Roberts, "Access Point Deployment Optimisation in Communication Based Train Control Data Communication System," IEEE transactions on intelligent transportation systems, vol. 19, no. 6, June 2018***

[56] ***Availability of a system***

Reply of Ministry/ GNCTD/ DMRC is not acceptable as it is possible to create competitiveness amongst vendors who supply wired connections. In spite of an open tender (where both wired and wireless connectivity was allowed), a vendor with wired connectivity had qualified for Line-7, which indicate that vendors with wired connectivity are available. Thus, explicit demand for wired connectivity would have ensured the vendors to supply Communication Based Train Control system with wired connectivity. Moreover, considering the advantages that wired connectivity provides, this should be made as a requirement. DMRC further, agreed to specify certain reliability specifications that every prospective vendor must satisfy to achieve the desired performance. Technical Consultant (IIT Delhi) suggested that reliability needs be measured differently for tunnels and viaduct and to prescribe different sets of specifications for each scenario. The reliability needs should also consider the future evolution of the metro, e.g. if they plan to run the trains with headway of 90 seconds, the reliability parameter should take that into account. A proper study of the actual channel between the Access Points and the duration of its going into deep fade (when the received power is too low to receive accurately) must also be examined.

(ii) Excess values of Mean Time between Hazardous Events, Mean Time to Repair and Mean Time between Failures

DMRC must quantitatively estimate the Communication Based Train Control performance safety requirements as is outlined in IEEE1474.1TM-2004[57]. DMRC should ensure that the total calculated aggregate Mean Time between Hazardous Events (a total of all critical and catastrophic hazards) is less than 10^9 operating hours. Also, IEEE 1474.1 TM-2004 specifies a Mean Time to Repair level 1 of less than 30 minutes and Mean Time between to Repair level 2 of less than 2 hours.

Table 2.3
Mean Time between Failures and Mean Time to Repair data for Line-7 and Line-8

Equipment	Line-7	Line-8
Computer based Interlocking	48,551.13	33,748.63
Communication Based Train Control on Board	245.05	366.37
Communication Based Train Control Wayside	9,325.83	1,24,749.73
Automatic Train Supervision	3,817.87	20,605.23
Mean time to Repair (in hrs) for line-7 and line-8		
Computer based Interlocking	5.29	6.26
Communication Based Train Control on Board	4.19	5.08
Communication Based Train Control Wayside	4.71	7.31
Automatic Train Supervision	9.98	10.50

[57] *Institute of Electrical and Electronics Engineers (IEEE) P1474.1 is a Standard for Communications-Based Train Control Performance and Functional Requirements*

Data provided by DMRC (Table 2.3) indicates that the Mean Time between Failures[58] and Mean Time to Repair values are relatively high. For example, values of Mean Time to Repair are greater than 4 hours and extend up to 10 hours, which is high. Also, the availability values reported by DMRC in its reply was 98.32 *per cent* for Line-7 system and 98.63 *per cent* for Line-8 system. In contrast, the requirement in Safety Integrity Levels-4 standard is of 99.999 *per cent*. Thus, the availability of the system is also low as compared to norms.

DMRC agreed that these values are low, as this is their first experience with the Communication Based Train Control system. DMRC also agreed for regular tracking of these parameters in future and to take proper action if some parameters are not found meeting the standard requirements. DMRC, however, failed to provide any data on Mean Time between Hazardous Events. It is imperative to ensure continuously gathering the value of parameters, namely, Mean Time between Failures, Mean Time to Repair, and availability, and to take proper corrective measures (re-planning routes, e.g., by reducing the frequency of the trains) if any of these are found not within their proper limits as a poor design of the Communication Based Train Control system will raise safety and performance issues (the frequent breakdown of the Communication Based Train Control system).

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that DMRC is implementing Communication Based Train Control for the first time and that all teething problems regarding design will be identified and resolved within the Defect Liability Period. DMRC is also continuously gathering various parameters namely, Mean Time between Failures, Mean Time to Repair and taking corrective measures to improve performance of the system. During Exit Conference (September 2020), DMRC stated that there has been no failure so far for their signalling system in terms of safety. Therefore, there parameters related to Mean Time between Hazardous Events are satisfactory. However, they have not calculated this parameter as there is no hazardous event so far to some extent.

In view of above, it is suggested that the parameters may be gathered and monitored by DMRC continuously and corrective measures should be taken as and when required.

(iii) Vulnerability to Interference and Jamming in the Communication Based Train Control

Communication Based Train Control system uses 2.4 GHz, which has the same spectrum as WiFi. This is likely to cause interference with the increase in mobile WiFi, besides being prone to intentional jamming of the signal. Several incidents of jamming of the Communication Based Train Control system have been reported in other countries. The Communication Based Train Control system of different lines uses different technologies as mentioned below:

[58] ***Mean Time between Failures should be greater than one lakh hours for an MTTR of 2 hours, for an availability of 59 seconds***

Table 2.4
Features of various signaling systems adopted

System	Advantages	Disadvantages
Nippon signalling, Line-8	Radios are not IEEE 802.11n compatible Uses code division multiple access (CDMA) and frequency division multiple access (FDMA)	Only uses 2.48 GHz
Bombardier transportation, Line-7	Radios are not IEEE 802.11n compatible Uses a direct sequence spread spectrum (DSSS)	Only uses 2.48 GHz
Ansaldo ATS, Noida metro	Uses two bands 2.48 GHz and 5.8 GHz	Use simple differential phase-shift keying (DPSK)

Audit along with the Technical Consultant (IIT Delhi) noted that irrespective of the physical layer solution adopted, there is no system immune to jamming, which remains a challenge for the Communication Based Train Control system working in 2.4 GHz. Thus, the best solution is to adopt the Communication Based Train Control system at some other licensed band so that the manufacturing of equipment in that band is strictly prohibited. Also, DMRC must conduct a test to measure the power required to jam various systems and assess a possibility for that. It is also important to note that in case of failure of the Communication Based Train Control system, the signalling system operates on the manual mode using the axle detectors and the axle detector slows down the trains, thereby affecting the revenues of DMRC.

DMRC acknowledged their awareness of the problem of interference and jamming and indicated that they have considered using a licensed spectrum in the past. However, this was not followed up as it would not be cost-effective.

It is recommended to carry out proper tests on the possibility of jamming and to identify the power levels at which various systems could be jammed. Based on the test results, DMRC must take proper corrective measures. Thus, DMRC needs to remain alert about interference and jamming and take appropriate action, as that and the arrival of 5G may further compound the problem of interference and jamming.

The Ministry/ GNCTD and DMRC has accepted (January 2021 and July 2020) the Audit observation.

2.5 Electrical issues

Electrical energy[59] is required for operation of metro system. Various issues related to procurement of traction transformer and auxiliary main transformer of higher size and non-optimal location of Receiving Substation in Phase-III were noticed.

[59] ***Receiving substation comprises of Traction & Auxiliary substations where Traction substation is for running of trains and Auxiliary substations for station services including illumination of buildings, air conditioning of underground stations, ventilation of tunnels, lifts, escalators, signaling, telecommunication, fire fighting, workshops, depots and other maintenance infrastructure within the premise of metro systems.***

(i) Traction Transformer

As per the DPR, the projected power demand was estimated to be 150 MVA on Line-7 and 90 MVA on Line-8 for the year 2031 for nine car 90 second headway operation. This was the basis on which the capacity and design of the Traction Transformer was done by DMRC. After deliberation, Managing Director DMRC decided to have six car operations on Line-7 and Line-8 during Phase-III. At the time of calculating the requirement of Traction Transformer, DMRC had taken 90 seconds headway which was not envisaged till 2046 as per Phase-IV DPR. Detailed Traction Simulation sizing Study was conducted by Detailed Design Consultant, Ardanuy Ingenieria on Line-7 and SYSTRA on Line-8. Five new Receiving Substation were constructed on Line-7 and three new Receiving Substation on Line-8 while one Receiving Substation at Botanical garden was augmented for Line-8. The power supply by each Receiving Substation catering to several metro stations is shown in the picture below:

Figure 2.6

Line-7 (55.697 km and 38 metro stations)

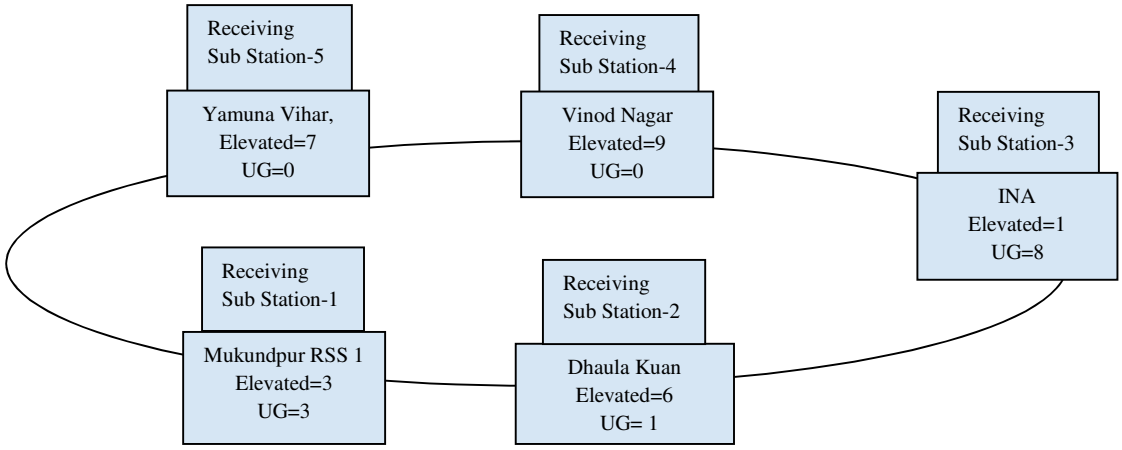

Figure 2.7

Line-8 (33.494 km and 25 metro stations)

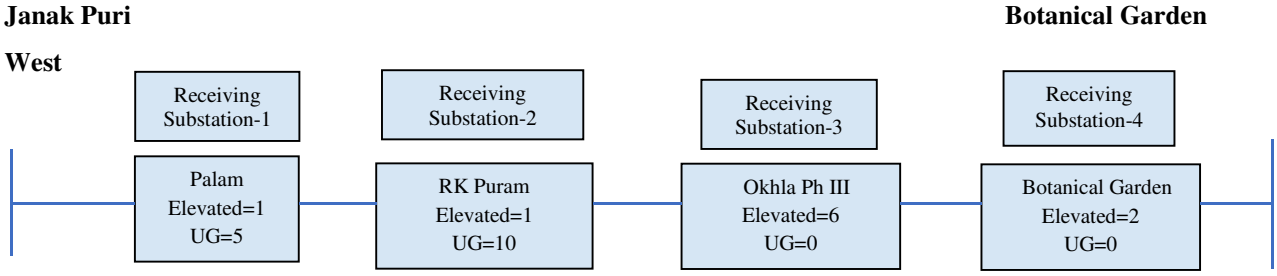

Table 2.5
Total power demand estimates as per DPR

Line	Corridor	2016	2021	2026	2031 (for 6 car)	Designed Headway of (9 car train at 90 Seconds)
7	Yamuna Vihar Mukundpur	69.9 (37.5+32.4)	80.6	89.8	110.7 (62.3+48.4)	198.7 (150.3+48.4)
8	Janak Puri West Kalindi Kunj	53.2 (18.5+34.7)	63	67.8	77.8 (31.4+46.4)	136.4 (90+46.4)

Audit along with Technical Consultant (IIT Delhi) observed that the estimated traction power for Line-7 is 62.3 MVA in 2031. The design of the Traction Power is mentioned as 150.3 MVA for 9 Car 90 seconds headway. Thus, higher value of designed power demand was assumed (150.3 MVA) for the traction purpose against required traction power of 62.3. For Line-8, requirement was 31.4 MVA and design was done for 90 MVA. This increase in power demand was without any proper justification. Any justification for this higher design for traction power was also not available in the DPR. Also, there exists an ambiguity in the number of car operation and headway[60] for deciding the traction power requirement for Line-7 and Line-8 within the DPR.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that Traction Power Requirement for nine Coach 90 second headway is 150 MVA (Line-7) and for six Coach 90 second headway is 100.2 MVA (Line-7). Five Receiving Substations were planned to feed a total of 54 km long Line-7. The total traction power requirement is 100 MVA for six Car configurations at 90 second headway. The capacity of Traction Transformer shall be designed based on N-1 configuration[61], therefore 40 MVA (100/5=20x2) traction transformer at each Receiving Substation is required and 40/ 50 MVA Traction Transformers have been installed.

The Ministry/ GNCTD/ DMRC reply is not acceptable as deciding the Traction Transformer capacity by the thumb rule and dividing the total power requirement with the number of Receiving Substation is technically not justified as observed by the Technical Consultant (IIT Delhi). Transformer capacity should be decided with proper simulation study for various train running conditions, load etc.

(ii) Traction Transformer for Line-7

a) Audit along with the Technical Consultant (IIT Delhi) observed that total Root Mean Square[62] power requirement for Line-7 is 75.352 Mega Volt Ampere (MVA). The maximum power drawn is for a very small time which depends on the gradient of the track, operating condition of the rail and other factors. It is observed that Root Mean Square loading of 12.114 MVA (Mukundpur), 19.605 MVA (Vinod Nagar) and

[60] ***In DPR Annexure 6.1 design of Receiving Substation considers nine car operation and Annexure 6.1.2 considers six cars***
[61] ***N-1 Configuration means when one Receiving Substation fails***
[62] ***Root Mean Square – The sizing of the Traction Transformers is done on the Root Mean Square power***

12.625 MVA (Yamuna Vihar), were well below the normal rating of 40 MVA. Hence, Traction Transformer can be of lesser capacity than 40/ 50 MVA in these stations.

b) Under normal operating condition (without contingency), the loading of all the Traction Transformers is not uniform, this could have been achieved at the planning stage, to make the loading uniform, thereby reducing the stress in contingency.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that the study was done with six coach configurations at headway of 135 second whereas system was designed for nine car configuration with 90 second headway. So, for design condition and for six car configuration 90 second headway condition, maximum MVA requirement will be greater than 132.416 MVA. Transformer at Mukundpur and Yamuna Vihar Receiving Substation are kept of the same rating for separability/ standardisation purpose. Further, during Phase-IV of the project, extension of Line-7 is also planned from Mukundpur to Maujpur-Babarpur corridor for an approx. length of 12.6 km. The traction power requirement of this extended corridor was also envisaged at the time of selection of rating of Traction Transformer. Further, the traction power requirement (Root Mean Square value) under (N-1) conditions are generally in the range from 38 MVA (Mukundpur) to 55 MVA (Dhaula Kuan). Hence, Traction Transformer of rating 40/ 50 MVA were selected.

The Ministry/ GNCTD/ DMRC reply is not acceptable as power requirement at each of the Traction Transformer throughout the line will never attain the maximum value at the same time and the total maximum power demand will never reach 132.416 MVA. It is not technically clear why all the transformers are of same capacity for separability/ standardisation purpose. This view is also endorsed by the Technical Consultant (IIT Delhi). The calculation/ simulation of power requirement for the Phase-IV project, where the extension of Line-7 is planned from Mukundpur to Maujpur-Babarpur corridor was not provided to justify the size of Mukundpur Traction Transformer. Further, DMRC is referring to old study report (June 2012) while giving the Root Mean Square values, whereas Audit had considered the subsequent report (September 2013). In the Exit Meeting, it was discussed and recommended that DMRC being a world class metro operator should carry out technical study to decide on the sizing of Traction Transformer.

(iii) Traction Transformer for Line-8

The scope of the study as per the Detailed Design Consultant contract is to validate the location of Receiving Substation and sizing of the transformers and cables. All the N-1 contingency (when one Receiving Substation fails) has been studied for a minimum of 135 Second headway for a portion of Line-8.

In the case of N-1 contingency, the maximum loading of Palam Traction Transformer is around 30 MVA and for Okhla just around 20 MVA. Besides, Traction Transformer at R K Puram is just 40 MVA even in contingency. Hence, the sizing of the transformer at all the three stations is oversized as observed by Audit along with the Technical

Consultant (IIT Delhi). Also, location of Receiving Substation was predefined rather than finding the optimal placement.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that the transformer of Palam Receiving Substation is at Dead End of the Line-8 and hence, its optimum capacity is not utilised. In Phase-IV, Botanical Garden-Janak Puri West corridor is proposed to be extended upto R K Ashram Marg. The traction power requirement of this extended portion will increase by 10 MW. Further, under (N-1) conditions, the Traction Transformer capacity works out generally in the range from 32 MVA (Okhla) to 55 MVA (R. K. Puram) at 90 second headway. Therefore, traction transformer capacity was decided based on the simulation report and with maximum capacity required under N-1 condition i.e., 40/ 50 MVA.

The reply of Ministry is not acceptable as no supporting calculation/ simulation document to justify why the additional size of 10 MW for Palam to dead end of the Line -8 (5 km approximately) was provided. Even additional loading of 10 MW (8 MVA) at Palam Traction Transformer will make the normal condition loading less than 30 MVA (17.143 + 8). The heavy loading at R K Puram and Okhla are during C2 and C3 mode, which are done at lower headway than C1 and C4 mode in N-3 contingency[63]. The study could have been done with the relaxation of these two modes to find the transformer loading. Hence, the sizing of all transformers is oversized, which would have resulted in the increase in size of the cables too.

(iv) Auxiliary Main Transformer

a) In Phase-I and Phase-II, DMRC constructed metro stations for eight car trains operations and the capacity of the auxiliary main transformer installed in the Receiving Substation was of 15 MVA and 30/ 45 MVA. In Phase-III, DMRC constructed metro stations for six car train operations on Line-7 & Line-8. However, each Receiving Substation has two auxiliary main transformer of 30/ 45 MVA.

b) For Line-7, Audit along with the Technical Consultant (IIT Delhi) observed that although the DPR envisages a total load demand of 48.4 MVA, the load demand based on which the auxiliary transformer (33 KVA) sizing was done by Ardanuy was 75.927 MVA. It was also observed that the maximum load required during the contingency is well below the capacity of 45 MVA. Some of the auxiliary main transformer could have been of lower rating as each Receiving Substation is of 30/ 45 MVA. Further contingency analysis done by the Detailed Design Consultant and DMRC are resulting in different MVA requirement. Hence, a proper sizing of the auxiliary main transformers at various Receiving Substation could have been achieved by making suitable number of stations attached to the auxiliary main transformer at a particular Receiving Substation.

c) For Line-8, Audit along with the Technical Consultant (IIT Delhi) observed that none of the auxiliary main transformer is reaching its natural rating of 30 MVA. The auxiliary main transformer at Okhla Phase-III is loaded to only 17 MVA and at Palam

[63] ***N-3 Configuration means when three Receiving Substation fails***

it is loaded to 21.5 MVA which are much below the normal rating of 30 MVA. Further, the contingency analysis is not found for the auxiliary main transformer by the Detailed Design Consultant. Further, with proper planning either the capacity of auxiliary main transformer at Palam or at Okhla could have been reduced.

Thus, the DMRC procured and installed auxiliary main transformer of higher capacity than the actual power requirement based on the size of stations of Line-7 and Line-8.

DMRC replied (July 2020) that in Phase-I & Phase-II, 15 MVA transformer were installed for the section supplying load to only elevated stations and 30/ 45 MVA auxiliary main transformers were installed for the section supplying load to both elevated and underground stations. Line-7 of Phase-III has a mixture of both elevated and underground Stations, therefore transformers of 30/ 45 MVA were installed. The Ministry replied (January 2021) that during detailed design stage, DMRC had considered load factor based on the past experience and demand of auxiliary power was reduced at each elevated station as 500 kW, at each underground station as 2,500 kW and at maintenance depot as 2,000 KW and was accordingly considered for calculating the rating of auxiliary main transformer at each Receiving Substation. To meet the requirement, 30/ 45 MVA transformer available as a standard product with the manufacturers was selected to cut down time as well as cost required for type testing for speedy completion of project.

The Ministry/ GNCTD/ DMRC reply is not acceptable as the size of the stations constructed during Phase–III were small as compared to stations constructed in Phase-I and II. Further, Technical Consultant (IIT Delhi) also stated that rather than deciding the capacity of the auxiliary main transformer based on the type of stations, it should be based on the power requirement calculation after proper study in the planning stage.

2.6 Heating, Ventilation, and Air Conditioning

Heating, Ventilation, and Air Conditioning is the technology of indoor and vehicular environmental comfort. Its goal is to provide thermal comfort and acceptable indoor air quality. Audit noticed the following in this regard:

2.6.1 Provision for Platform Screen Doors

Platform Screen Doors, also known as Platform Edge Doors, are used at train or subway stations to separate the platform from trains. Platform Screen Doors act as a physical barrier preventing people or objects from falling onto the tracks. Platform Screen Doors also improve climate control within the station. In Phase-III, DMRC adopted half height Platform Edge Doors, mainly from the passenger safety point of view. Since decision for investment in Platform Edge Doors infrastructure was already made, switching to full height Platform Screen Doors would not have caused any significant cost increment.

Figure 2.8

Full Height Platform Screen Doors and Half Height Platform Edge Doors

Audit along with the Technical Consultant (IIT Delhi) observed that the matter of using Platform Screen Doors is an important one for underground station design and Heating Ventilation and Air Conditioning energy savings, DMRC did not carry out an extensive study on the Platform Screen Doors in Phase-III, even though civil structure for the same was part of the DPR. This was despite availability of design experience from the two earlier Phases of DMRC, and other metro agencies in the country (Chennai Metro, Airport Line in Delhi etc.), going ahead with full height Platform Screen Doors for energy savings in similar timeframe.

It was also observed that tunnel cooling is only needed in extreme weather (ambient T>43^{o} C), and congested mode operation with trains stopping in the tunnel. Such short duration loads can be catered by tunnel ventilation and by thermal inertia of tunnel. But the use of Platform Screen Doors may help in reducing the station Heating Ventilation and Air Conditioning load substantially.

The station heat load summary for reviewed stations indicated that typically more than 60 *per cent* of station air conditioning load are Subway Environment Simulation loads, or heat coming from the tunnel. With the help of Platform Screen Doors, the station air-conditioning load would have reduced significantly, leading to smaller Heating Ventilation and Air Conditioning capacity requirement. This would also result in lower requirements of electrical infrastructure and space needed for the station Heating Ventilation and Air Conditioning equipment including ducting.

Thus, DMRC installed half height Platform Screen Doors without energy saving studies. This has resulted in installation of higher capacity electrical equipment and consequent higher operation & maintenance cost.

The Ministry/ GNCTD and DMRC replied (January 2021 and July 2020) that with the introduction of full height Platform Screen Doors, the station loads are decreased but it necessitates the provision of tunnel cooling. Platform Edge Doors in Phase-III have been provided majorly to control crowd at the platform. It was also submitted that

based on this observation, during extreme ambient conditions, active tunnel cooling would be required. This is achieved by locally cooling tunnel air at a number of locations. The motion of the train carries the cooled air down the tunnels. The heated air at the end of the tunnel run is captured by the track way exhaust system and recirculated to an air handling unit for re-cooling. Cooled air is then also available to be directed across stalled trains during congestion. If the total cooling required per station to achieve design limits in this way is less than that evaluated as part of the non-Platform Screen Doors analysis, the plant capacity initially installed would be adequate to perform satisfactorily when platform screen doors are installed. Therefore, to deal with the congestion during the summer months (15 April to 15 July), it is required to regularly cool the tunnel so that cooled air is available to be directed by Tunnel Ventilation Fan in case of congestion. In Phase-IV, full height Platform Screen Doors has been considered in view of the increased headway of about four to five minutes of upcoming corridors.

The reply of the Ministry/ GNCTD/ DMRC is not tenable because their response on Platform Screen Doors was not justified through any studies so far. It seems more like an expectation or general statement about the suitability of Platform Screen Doors for increased headway in Phase-IV and needs to be qualified with more detailed studies. The active tunnel cooling and recirculation of heated air through Air Handling Unit also needs to be evaluated by DMRC more critically and carefully from all perspectives. With Phase-IV already underway, the strategy and detailed design calculations of implementation of Platform Screen Doors seem to have been much delayed.

2.6.2 Tunnel Ventilation and Fire safety

The importance of Tunnel Ventilation and Fire safety aspects in underground station design cannot be understated as it concerns with safety of human lives. It also received significant attention in the design documents reviewed. It could be said that there is no major concern with the tunnel ventilation, fire-safety and smoke extraction arrangements.

The Ministry/ GNCTD in its reply (January 2021) has accepted the Audit observation.

Conclusion

DMRC's funding plan for three Phase-III corridors was in contravention of National Urban Transport Policy, 2006 as GoI contribution towards capital cost exceeded the 20 *per cent* limit, resulting in excess contribution of ₹421.34 crore. DMRC recommended two financially unviable corridors (Badarpur-Faridabad and Maujpur-Shiv Vihar) with negative Financial Internal Rate of Return, one corridor (Najafgarh-Dhansa Bus Stand) having below benchmark Financial Internal Rate of Return of 8 *per cent* and considered inflated Fare Box Revenue to make the four corridors of (i) Dilshad Garden to Ghaziabad, New Bus Adda, (ii) Noida City Centre to Noida Sector-62, (iii) Kalindi Kunj metro- Botanical Garden, and (iv) YMCA Chowk (Faridabad) to Ballabhgarh viable.

Further, in violation of the MoUD Guidelines, a chapter on Comprehensive Mobility Plan highlighting the development of an integrated plan was not included in the Phase-III DPR formulated by DMRC. Resultantly, integrated planning with respect to land use and transport, integration of various modes (fares, routes, and facilities) and institutional framework for coordination was not ensured by DMRC.

In the absence of any internal guidelines/ Standard Operating Procedures of DMRC for preparation of DPRs, DPRs were prepared on different assumptions. Detailed Project Reports of three corridors (Dwarka-Najafgarh, Mundka-Bahadurgarh and Maujpur-Shiv Vihar) were prepared in contravention of guidelines of Working Group on Urban Transport and RITES study as other modes of transport like Light Metro/ Bus Rapid Transit were not explored. Resultantly, high capital cost was infused into the projects and consequent higher operation and maintenance cost. DMRC also recommended two financially unviable corridors (Dwarka-Najafgarh and Mundka-Bahadurgarh) after considering revenue from Property Development without ensuring the availability of required land.

DMRC changed the train operation from nine cars to six cars without detailed justification after sanctioning of Phase-III projects eliminating the possibility of further expansion to cater the increase in future ridership. DMRC procured rails of relatively low hardness which may result in increased maintenance cost due to decreased life of rails and wheels. DMRC also procured higher capacity of Traction Transformer due to estimation of higher projected demand, which resulted in higher capital expenditure. Further, DMRC procured and installed Auxiliary Main Transformer of higher capacity than the actual power requirement in Line-7 and Line-8. Half height Platform Screen Doors were installed instead of full height Platform Screen Doors resulting in installation of higher capacity electrical equipment and consequent higher operation & maintenance cost.

Thus, various deficiencies were noticed in the planning process adopted by DMRC adversely affecting the operations and financial viability of the MRTS as brought out in the chapter on operation and maintenance and Revenue Management. Besides, the deficiencies also affected the selection of the most appropriate technology.

Recommendations

1. ***DMRC should ensure at the project planning stage itself that Detailed Project Reports are prepared with realistic assumptions for computation of Financial Internal Rate of Return to ensure economic viability of the corridor.***
2. ***DMRC may formulate a policy for selection of type of corridor, interchange between two stations, and mode of interchange facility, which would benefit future Mass Rapid Transit System projects in the country. Also, the policy document may clearly define the circumstances under which deviations from the stated policies are allowed.***
3. ***DMRC may consider preparing Guidelines/ Standard operating Procedures for formulation of the Detailed Project Reports for future metro rail projects/***

expansion. The revised Detailed Project Reports may be approved by the Board of Directors before submission to Government of India and Government of National Capital Territory of Delhi.

4. *A Guideline/ criteria for selection of mode of transport for different scenarios like Light Metro, Bus Rapid Transit system based on viability and alternative analysis may be formulated.*

5. *DMRC should ensure timely availability of land for Property Development which is of paramount importance to make the project financially viable.*

6. *DMRC may consider optimising the sizing of Traction Transformers in Receiving Sub Stations instead of putting transformers of uniform capacity across all Receiving Substation on a Line.*

7. *DMRC may consider full height Platform Screen Doors including evaluation of its effect on Heating, Ventilation and Air Conditioning requirements in the under-ground station design studies.*