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都市鉄道の高架・地下路線選定の妥当性 ジャカルタ都市高速鉄道事業計画と日本における 都市地下鉄計画事例の比較検証

Suitable selection of elevated and underground routes for urban railway-comparison of JAKARTA MRT planning and underground railway planning and development in Japan

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Urban railway operation is required as a public service with financially viable operation management. Considering this requirement, the route and alignment planning for Jakarta Mass Rapid Transit (MRT), the first of its kind in Indonesia to use a combination of underground and elevated segments, will be selected by thorough investigation of various aspects including area terrain, geology, city aesthetics, transportation system, construction method, project costs and environmental impacts to the nearby residents, etc. In fact, most operators prefer to choose the elevated route, mainly due to the budget constraints for construction cost.

The authors analyzed actual urban railway planning and development examples in Japan and compared them with the Jakarta MRT Project. The selection of elevated and underground segments for Jakarta MRT Project was deemed to be justified by the assessment of various cases in Japan based on the following main evaluation factors: 1) cost comparison including land acquisition, 2) financial impact to railway operator, 3) environmental assessment including aesthetics and climate condition, and 4) synergy effect by joint development of railway and adjacent area with positive land valuation.

Key Words : *Jakarta MRT, Elevated and Underground Comparison, Underground Subway, Railway Grade Separation*

1. Jakarta Mass Rapid Transit Project

(1) Outline of Jakarta MRT Project

Jakarta, Capitol City of Indonesia, and its surrounding metropolitan area covering 6,580 km^2, has a population over 21 million and is situated as the center of political, economic and social activities of the country. It also has typical urban problems such as traffic congestion, environmental deterioration, and inflation of land prices, etc. To alleviate Jakarta City from urban traffic problems of chronic road congestion, Mass Rapid Transit (MRT) was initially proposed along the main north-south axis road through the city center, so-called as the Jakarta Subway.

Since 1990s, the Indonesian Government carried out the study on Jakarta MRT Project for various alternatives with elevated and underground segments and recently established the Implementation Program for Project Execution under the financial assistance by ODA from Japan. As the guideline for bilateral finance project in Indonesia, the ceiling amount of ODA Loan from Japan is anticipated to be about Yen 50 billion per project. Under this financial constraint, MRT Project aims at the initial open for public services between the City Center (Monas) and Suburban Bus-Terminal (Lebak Bulus) covering about 15 km length and including elevated and underground segments.

キーワード：ジャカルタ都市高速鉄道，高架･地下比較検討，地下都市鉄道，鉄道立体交差
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(2) Current Condition of Transportation Network in Jakarta City

Jakarta City Center and Central Business District (CBD) are stretching from Monas, the independent monument park, along which the main north-south axis road, Thamrin to Sudirman Street, is running. Two circular toll roads surround the Jakarta urban and suburban area and connect with the inter-city toll road network. Jakarta and suburban railway network compose an almost circular route around Jakarta urban area and the radial routes extending to the suburban area. Thus, the present transportation network of toll roads and railway covers a wide suburban area, but does not have direct connection to the City Center (Monas) and CBD area. Therefore, the use of private vehicle or public bus is needed for access to this area and the resulting road traffic congestion is a serious problem.

As a countermeasure to this situation, a vehicle traffic restriction has been applied to the major axis road of Sudirman, Thamrin and Gatot Subroto Streets since 1990 to allow only vehicles with more than three passengers to enter during the morning and afternoon rush times. However, this restriction has not improved urban road traffic conditions due to the increasing number of vehicles and the lack of any alternative access to the road network. In 2004, the public Trans-Jakarta Bus System was opened along the north-south axis road between Jakarta Kota and Blok M route, the same route as the initial proposal of the Jakarta Subway. This Bus System is the first public transport system to use an exclusive lane of the main axis road through Jakarta City Center (Monas) and CBD area.

In order to facilitate the mass transport system for access to Jakarta City Center and CBD from the suburban area and also to connect this system with the newly operating Jakarta Bus System, Jakarta MRT Project is urgently required to alleviate the current transportation situation in Jakarta City. MRT Project route and planned transportation network are shown in **Figure-1** with the site photo at Thamrin Street through the City Center.

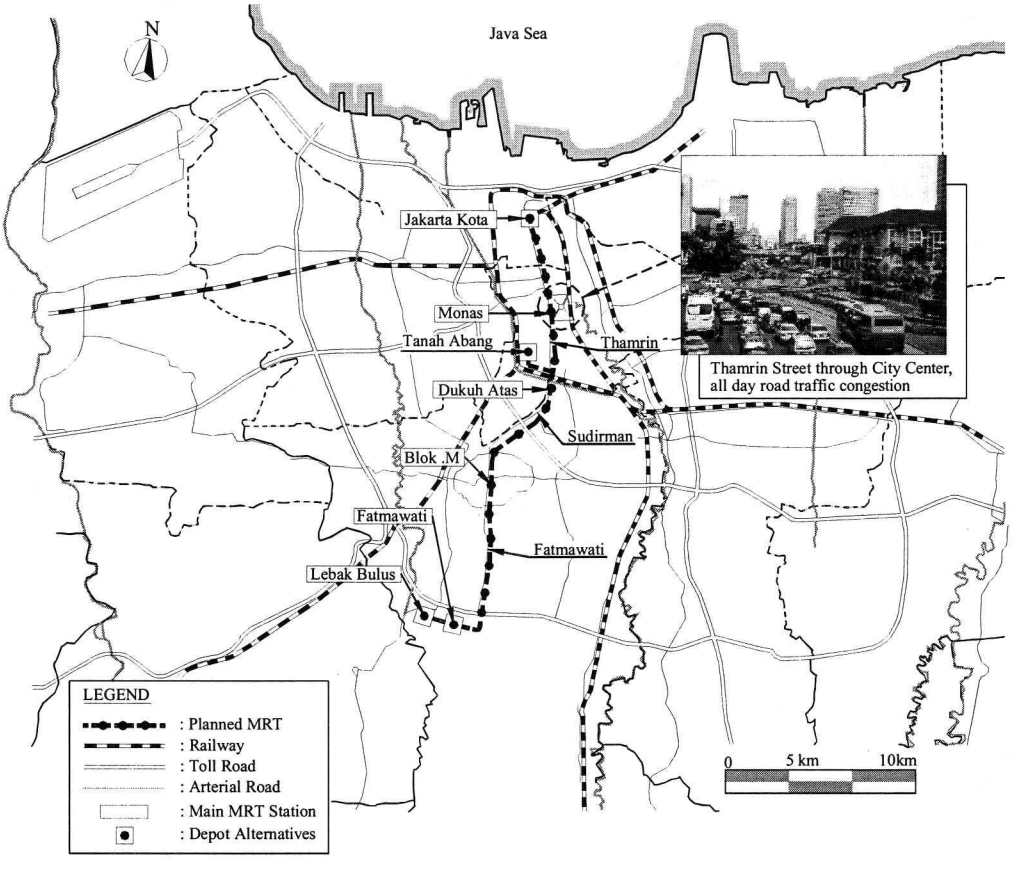


Figure-1 Jakarta MRT Project Route and Planned Transportation Network

(3) Comparison of Alternatives in Jakarta MRT Project

Following the initial plan with underground segments for the entire section between Jakarta Kota and Blok M proposed by Basic Design in 1996, four alternative plans were developed prior to the Indonesian Government establishing the execution plan for Jakarta MRT Project in 2004. Most of these alternatives were studied seeking to reduce the project cost to comply with financial constraints. Basic Design and these Alternatives, which were developed by the various studies for the Indonesian Government, are compared in **Table-1** and summarized in **Figure-2**.

Table-1 Comparison of Alternatives in Jakarta MRT Project

Plan	Study (Year)	Route Length
Basic Design	IJEG Study (1996)	(U): 15.0km, (E): 0.0km, (T): 15.0km
Alternative 1	JTCA Study (1999)	(U): 6.6km, (E): 8.3km, (T): 14.9km
Alternative 2	JICA Study[1)] (2001)	(U): 7.5km, (E): 8.0km, (T): 15.5km
Alternative 3	METI Study (2003)	(U): 2.0km, (E): 5.8km, (T): 8.3km
Alternative 4	IPPE Study (2004)	(U): 3.1km, (E):11.2km, (T): 14.3km

NOTES

IJEG : Indonesian, Japanese and European Group
JTCA : Japan Transportation Cooperation Association
JICA : Japan International Cooperation Agency
METI : Ministry of Economy, Trade and Industry, Japan
IPPE : Implementation Program for Project Execution, Indonesian Government

(U): Underground Route
(E): Elevated Route
(T): Total Route

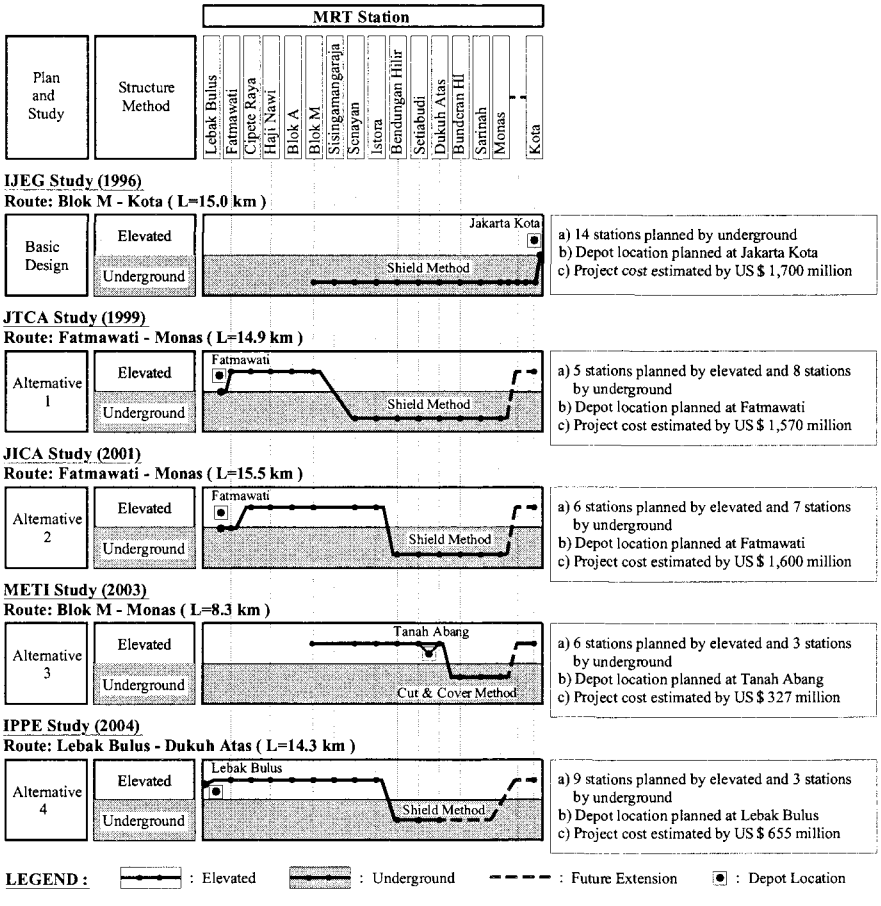


Figure-2 Alternative Analysis on Jakarta MRT Project

2. Selection of Underground Route for Jakarta MRT Project

(1) Comparison between Elevated and Underground Method

For route selection and planning of railway in the urban area, underground method is generally selected considering the difficulty of land acquisition, and in the suburban area, elevated method is mostly selected. Therefore, the suitable combination between elevated and underground segments is a key factor of railway route selection and alignment. As shown in **Table-2**, underground has the biggest demerit of higher construction cost, which is generally estimated as two or three times that of the elevated. However, underground has the obvious general merit in terms of urban aesthetic protection, noise, stability during earthquakes, etc.

Table-2 Comparison of Elevated and Underground Method

Item	Elevated Method	Underground Method
Aesthetic View	Negative result on major roads	No negative result
Land Acquisition	Space for superstructure required	No major requirement on ground
Environmental Impact	Noise protection etc. required	Flood protection etc. required
Civil Structural Cost Estimate	US$ 8.1 million/km by MRT Project	US$ 19.0 million/km by MRT Project

Physical route selection of Jakarta MRT Project has required the detailed analysis of area conditions along the planning route and the finance limitations for construction cost. Basic data collected for Jakarta MRT Project and type of study results are summarized in **Table-3**.

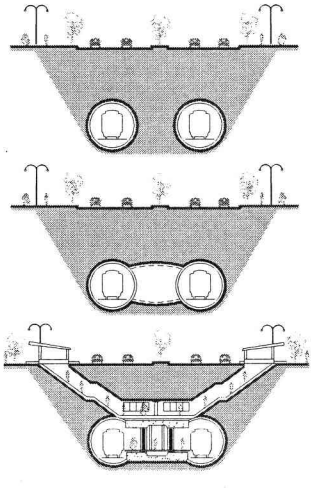
Table-3 Basic Data and Type of Study Result

Basic Data	Type of Study Result
Person Trip Mode Analysis along Planned MRT Corridor	Transport network planning
Passenger Volume Estimate at the Planned MRT Station	Ridership and income estimate
Land Settlement Record in Jakarta City Area	Structure and facility designing
Rainfall Record in Jakarta City Area	Drainage facility planning
Potential Flooding Area and Existing Deep Well Location	Flood protection designing
Geological Profile along Planned MRT Corridor	Construction method planning

(2) Consideration of Other Alternative for Using Underground Space

a) Alternative by Postponing Construction of Underground Station

All the above alternatives were analyzed and compared for cost reduction by shortening the initial construction route including construction of the stations for the public opening stage. From the viewpoint of shortening the route, there are other alternatives for cost reduction, to simplify the station facility or to exclude intermediate stations from the initial construction stage (i.e., to construct these stations in a later stage after achieving sufficient passenger demand as shown in **Figure-3**). In this latter alternative, there would be six intermediate stations along Fatmawati and Sudirman Streets (namely, Cipete Raya, Haji Nawi, Blok A, Senayan, Istora, and Setiabudi Stations) to be eliminated from initial construction based on the passenger demand forecast.



Construct underground route without station (initial stage)

Construct underground station (operation stage)

Open underground station (future stage)

Figure-3 Alternative by Postponing Construction of Underground Station from Initial Opening Stage

Elimination of these stations from the initial construction will reduce the construction cost estimate by around Yen 20 billion, which could be utilized for extension for suburban service to the southern route by underground method between Blok M and Lebak Bulus. In terms of railway service, this alternative has the advantage to transport longer distance travelers, and this aspect will be considered for railway planning and operation analysis in the initial stage.

In the case of Tokyo Metro Company (Formerly Tokyo Mass Rapid Transit Authority), Nishi-Shinjuku Station on the Marunouchi-Line was opened a long time after the main line opening. In another case of Tokyo Metro Company, many passengers on Hanzohmon-Line suffered the inconvenience of the service route terminating at Suitengumae Station. Therefore, many years after the opening of Hanzohmon-Line, the entire route was extended by service between Suitengumae and Oshiage; thereafter, the yearly passenger volume recorded a 17% increase on this Line, which was calculated as equivalent to 1.6% increase on all the lines of Tokyo Metro Company.

Again, reviewing the insufficient right-of-way for elevated structure construction compared with the existing road width between Blok M and Fatmawati and also the lower urgency of intermediate station construction, the underground method by two single shield systems might be considered as another viable alternative.

b) Alternative by Staging Construction of Underground Station

One general aspect of the current situation is that major government buildings and embassy buildings are located on the section between Monas and Dukuh Atas along Thamrin Street as main axis road in Jakarta City; this presents a beautiful aesthetic view combined with monuments. The proposal to construct an elevated structure along Thamrin Street will cause unsightliness and objection to the proposal.

As a solution, an alternative plan is proposed as follows: Dukuh Atas Station is planned at-grade, the same level as Thamrin Street, and from this station, the MRT profile is planned to descend by 3.5% grade, and to construct temporary type station (as shown in **Figure-4**) at Bunderan HI, Sarinah and Monas Stations. The temporary type station means construction of underground platform with transfer facilities at the ground level. Therefore, the passengers changing direction will be crossing over the street in the temporary stage, and then in the future, through an underground concourse which will be constructed later for saving the initial construction cost.

For designing the underground station, it is necessary to consider water protection procedures such as higher steps to shield against flooding, etc. due to the cloud-burst rain pattern in the tropical climate of Jakarta. Referring to the available data, maximum flood water level will be in the range between 61 and 100 cm along the planned MRT route.

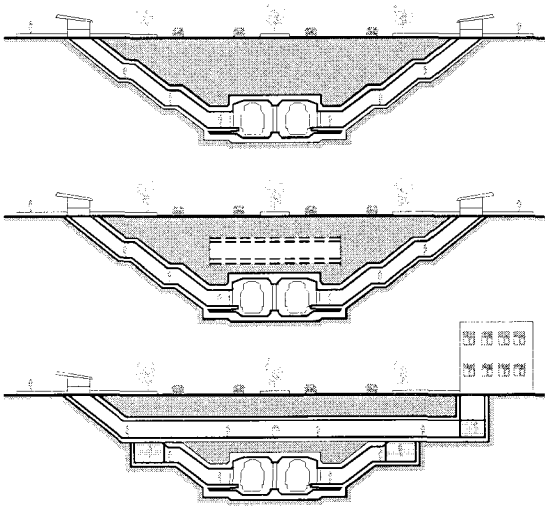


Figure-4 Alternative by Staging Construction of Underground Station as Temporary and Permanent Type

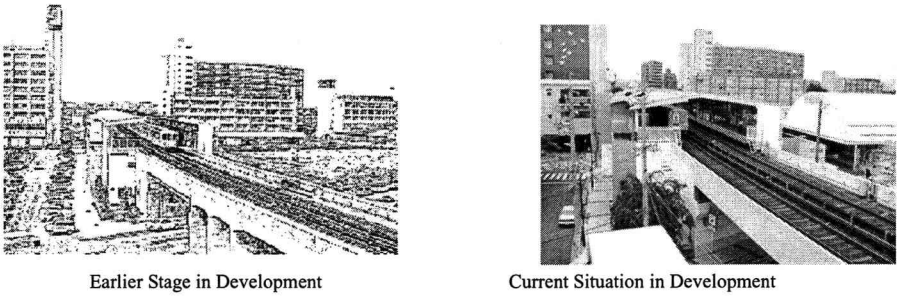
3. Analysis of Urban Railway Planning and Development Examples in Japan

Urban railway development examples in Japan were analyzed by research for the various references and interview to the authorized officers and the results are as described below.

(1) Nagoya City Subway, Higashiyama-Line

For new construction of Higashiyama-Line, an elevated structure was considered at the initial planning stage by Nagoya City Council to save the total project funds by its cheaper construction cost. However, the City Council eventually decided on the underground method for the first construction section, Nagoya – Sakae route of Higashiyama-Line, following the protest from the local residents, saying that the land value along the route would decrease in the future from the negative impacts of the elevated structure and railway operation.[2)]

Extension of subway was also executed by the underground method for the second section, Sakae – Ikeshita route of the Line after reassessment of elevated and underground methods. Thereafter, the underground segment was extended again for the third section, Hoshigaoka – Fujigaoka route of this Line, a part of which was executed by the joint construction for subway and housing as part of total city development sharing the necessary area for housing lots, railway and station facilities thus involving cooperation between housing area development and transport system development. On the entire route of Higashiyama-Line, the only ending section, Kamisha – Fujigaoka route was completed by the elevated method due to suburban area conditions (See **Photo-1**).



Earlier Stage in Development　　Current Situation in Development

Photo-1 Fujigaoka Station Area, Nagoya City Subway, Higashiyama-Line

(2) Sapporo City Rapid Transit System, Nanpoku-Line

Nanpoku-Line was originally planned as north-south axis link through Sapporo City of 25 km route, and the central segment of this Link, Kita24Jyo – Makomanai section of 12.6 km route, was scheduled to complete the construction and start operation in February 1972 when the 11th Sapporo Winter Olympic Games were opened. The original plan of this route used the elevated structure method considering the cheaper construction costs, except for the city center section between Kita16Jyo and Nakajimakouen, which was originally planned by the underground method due to difficult conditions for elevated structure construction.[3)]

Although Sapporo City Council proposed to the Former Ministry of Construction (currently, the Ministry of Land, Infrastructure and Transport) that the elevated method be used for the major part of this Line for saving construction cost, the Ministry did not accept this proposal of the Council, insisting that the elevated structure along the major road would cause various problems under the heavy snowfall or the frozen area condition. Following to this guidance by the Ministry, the Council decided to use the underground method for this Line, except for the elevated section between Hiragishi and Makomanai, which route was constructed on the available right-of-way after the removal of Jyohzankei Railway Line and completed with the snow shelter to protect the elevated structure and railway facility (See **Photo-2**).

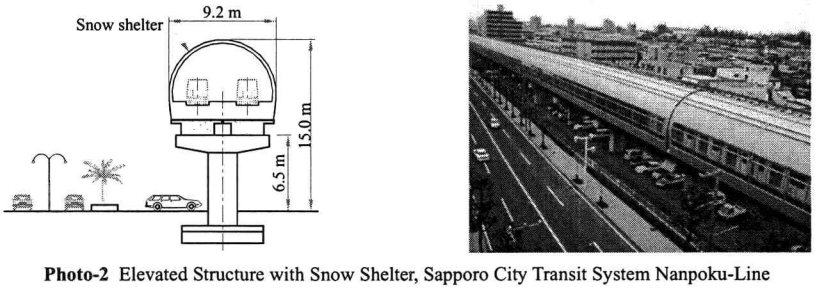


Photo-2 Elevated Structure with Snow Shelter, Sapporo City Transit System Nanpoku-Line

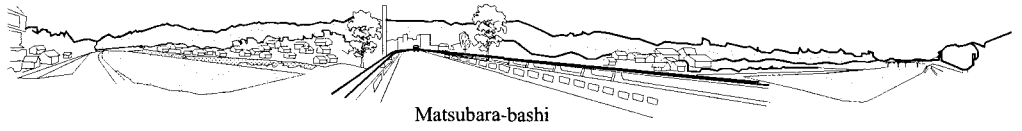
(3) Keihan Electric Railway Company, Tohfukuji – Sanjyo Route Railway Grade Separation

Keihan Main-Line was formerly operated by at-grade crossing railway routes through the city center of Kyoto along popular rivers such as Kamogawa and crossing with major roads such as National Road 1 and other parallel streets on the section between Shichijyo and Sanjyo streets.

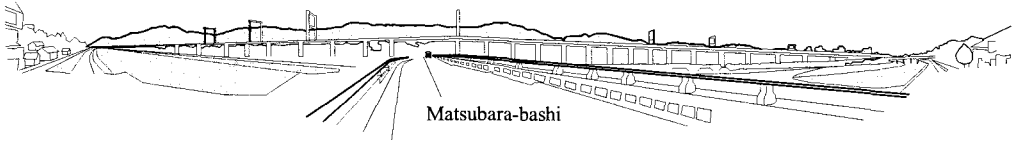
Due to this situation, Kyoto City Council and Keihan Railway Company planned the railway grade separation of Keihan Main-Line to mitigate chronic road traffic congestion by eliminating the railway level crossings and providing an additional city road along Kamogawa after removal of the at-grade railway. Grade separation plan was analyzed by comparison study between the elevated and underground method, including new Kamogawa riverside road construction and road network improvement, as well as railway grade separation (See **Figure-5**).

Finally the City Council and Railway Company selected the underground method for railway grade separation, which resulted in decreasing the total project cost to reduce the land acquisition cost by utilizing the removed railway area for the new road construction space after underground railway construction.

By comparing only the railway construction costs, the elevated method would be cheaper than the underground method, and will be usually chosen for railway grade separation. However, the underground method was unusually decided for Keihan Main-Line by the total project cost being cheaper than the elevated method for the railway and road combined construction. The underground method was also accepted for preservation of aesthetic view in Kamogawa area and the popularity of Kyoto City.[4)]



Perspective view before project from Matsubara-bashi to Shijyo and Gojyo direction



Perspective view after project from the same position to the a bove picture

Figure-5 Keihan Main-Line, Tohfukuji – Sanjyo Route Railway Grade Separation

(4) Odakyu Electric Railway Company, Odawara-Line Grade Separation and Double-Double Tracking

Improvement of Odawara-Line for the grade separation and double-double tracking was decided by the new joint operation plan with Tokyo Metro Line No. 9 (See **Figure-6**). As the first stage of this improvement, Kitami – Umegaoka route was planned by the elevated method for almost the entire route, except Seijyogakuenmae station area, which was constructed by cut and cover method due to the area terrain and track alignment. Final decision of the elevated method for this section was made by the total project cost being overwhelmingly cheaper compared with the underground method (Elevated method: estimated as Yen 190 billion, Underground method: Yen 300 ~ 360 billion). For the second stage of Umegaoka – Yoyogiuehara section, the cost of elevated method was estimated including the extra cost for higher elevated structure to pass over the other existing elevated railway structure of Keio Inokashira-Line, eventually almost the same cost as the underground method. Therefore, the underground method was selected, considering its smaller construction area compared with the elevated method.[5)]

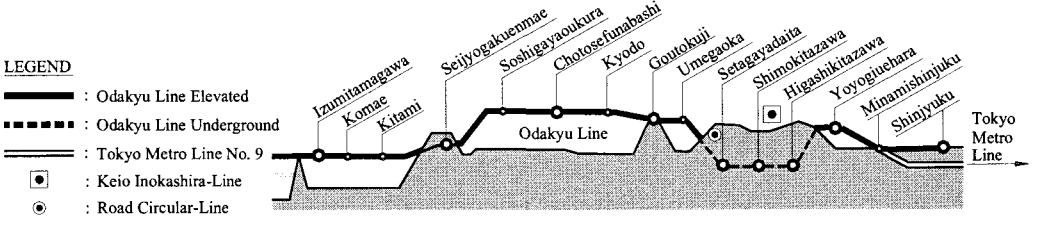


Figure-6 Odakyu, Odawara-Line Grade Separation and Double-Double Tracking

Comparison of the elevated, the underground or the combined methods at Shimokitazawa section of Odawara-Line was evaluated by the project plan, cost and related area aspects as summarized in Table-4.

According to the Government Regulations in Japan, subsidy for new railway construction will be provided to the railway company based on the elevated railway construction cost. In case of the underground railway construction cost exceeding the elevated one, the subsidy will be limited to the elevated cost and all other excess costs shall be borne by the railway company. This subsidy procedure also should be considered for selection of the elevated or underground method as well as the total project cost.

Table-4 Comparison of Grade Separation and Double-Double Tracking Method at Shimokitazawa Section, Odawara-Line

Method	Elevated	Underground		Elevated+Underground
Structure Plan	4-track (above ground) at same height	4-track (under ground) at same depth	2-track (under) and 2-layer (deeper) (*1)	2-track (above), 2-track (under) respectively
Route Alignment	Height required by elevated railway Inokashira-Line	Depth required by road Circular-Line No. 7	Depth required by road Circular-Line No. 7	Depth required by road and height by railway
Grade Separation	9 road crossings eliminated by grade separation	9 crossings eliminated by grade separation	9 crossings eliminated by grade separation	9 crossings eliminated by grade separation
Cost Analysis (*2)	Total project cost approx. Yen 140 billion	Total project cost approx. Yen 155 billion	Total project cost approx. Yen 140 billion	Total project cost approx. Yen 145 billion
Project Related Area	Larger area (approx. 15,000m^2)	Not estimated	Smaller area (approx. 2,000m^2)	Not estimated

(*1): Proposal by Urban Planning Bureau
(*2): Project cost estimated by general plan

(5) Keio Electric Railway Company, Kokuryo – Chofu Route Railway Grade Separation

Keio Main-Line, Shinjuku – Chofu Route is under execution for various railway improvements with section-by-section double-double tracking or track elevation, etc. Among others, Kokuryo-Fuda-Chofu Section was proposed for continuous railway grade separation aiming at eliminating the existing road crossings and developing new urban roads to cross this section and Chofu-Keiotamagawa section, which is branching route from Chofu Station (See **Figure-7**).

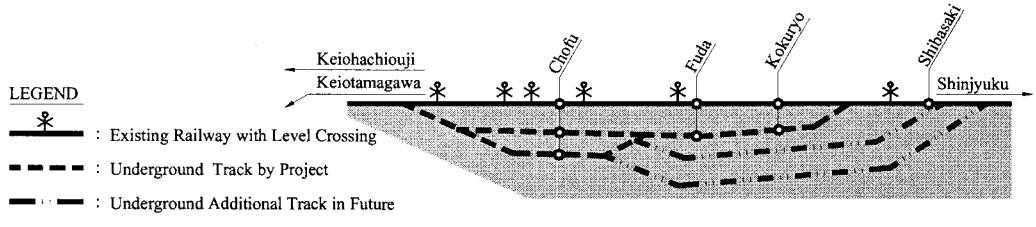


Figure-7 Keiyo Main-Line, Kokuryo - Chofu Route Railway Grade Separation

Cost comparison between the elevated and underground method indicated that almost same prices were estimated in the planning stage. Recent cost review by land devaluation is showing that the elevated method will be possible to become cheaper than the underground method. However, Keio Railway Company has decided on the underground method, undertaking to cover any extra costs at the Company's expense. Keio Company's decision implies that the underground method has an extra advantage to the local residents by allowing development of the existing railway area into a public park or other social use as well as eliminating the existing level crossings, and that this type of railway improvement can be implemented with partial costs sharing by the railway users as one of the beneficiaries of railway improvement. Total advantages of this continuous grade separation project by underground method include road traffic improvement by elimination of the existing level crossings and construction of the new road network, safety improvement for both of railway and road transport, area development by reusing the railway area with urbanization into a modern city and the passenger service improvement at the transit station, etc.[6)]

4. Justification for Selection of Elevated and Underground Routes for Jakarta MRT Project

(1) Suitable Selection of Elevated and Underground Route for Jakarta MRT Project

By combining all the alternatives described in Section 1.(3) with the new alternatives proposed in Section 2.(2), the entire connection between City Center (Monas) and Suburban Bus-Terminal (Lebak Bulus) shall be planned for Jakarta MRT Project and the city center route and suburban route will be underground method and the middle route will be elevated method. The city center route, Monas – Dukuh Atas Section is required to be underground method to protect the monumental aesthetics along Thamrin Street. Suburban route, Blok M – Lebak Bulus Section also is proposed by underground method to avoid the necessary land acquisition for elevated method along Fatmawati Street and to save the construction cost by single shield method without station construction at the initial opening stage (See **Figure-8**). Accordingly, Jakarta MRT Project will be totally planned with consideration of efficient operation for expecting sufficient passenger demand by connecting the city center with the suburban area, which will contribute to the financial viability of Jakarta MRT operation.

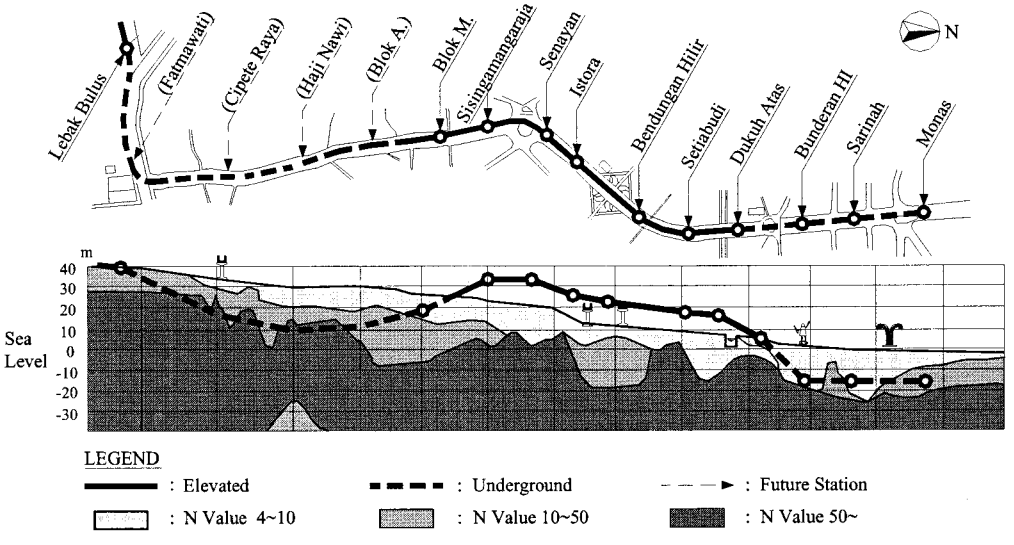


Figure-8 Suitable Selection of Underground and Elevated Routes for Jakarta MRT Project

(2) Assessment of Jakarta MRT Project by Similar Cases in Japan

For selection of elevated or underground method, the first consideration is the project cost comparison including land acquisition and its financial impact to the railway operator. In general, project cost saving is considered for any project implementation, and likewise is required by the public railway operator especially for the total operational profitability as indicated by similar cases in Japan.

The second consideration is environmental requirement including aesthetics. In case of Keihan Main-Line Railway Grade Separation of Kyoto City, the underground was originally planned as a suitable method based on the environmental requirement and the necessity for aesthetic preservation, even though by comparison study with the elevated method, the underground was assessed as acceptable method with the cheaper project cost estimate including the railway and urban road combined project. In Sapporo City, the elevated method in the snow prone and frozen area was not accepted due to environmental requirements and for safety reasons.

As the third consideration, local residents requests or public opinion was noted. In Nagoya City, the underground method was decided on due to the protest by the local residents concern about the devaluation of land values by the elevated railway. In case of Keio Main-Line Railway Grade Separation, the underground method was chosen by considering the local residents and railway users for the area development and public facility use with the allowable cost sharing by the railway operator.

Reviewing the above cases, the main evaluation factors considered for selection of the elevated or underground are summarized as follows: 1) cost comparison including land acquisition, 2) financial impact to railway operator, 3) environmental assessment including aesthetics and climate condition, and 4) synergy effect by joint development of railway and adjacent area with positive land valuation.

Based on the above-summarized four evaluation factors, assessment of the Jakarta MRT Project is shown in **Table-5**. Project cost saving was planned by combination of the necessary underground routes and the remaining elevated route in order to fulfill the financial constraint by ODA Loan from Japan and also to connect the city center with the suburban area for efficient railway operation and ridership. With these factors, Jakarta MRT is anticipated to provide the public transport service between the City Center (Monas) and the Suburban Bus-Terminal (Lebak Bulus) with the estimated passenger demand around 350,000 passenger/day in 2015. The selection of underground method for Jakarta MRT Project is justified by similar examples in Japan.

Table-5 Assessment of Jakarta MRT Project by Evaluation Factor

Evaluation Factor	Assessment
1) Cost comparison including land acquisition	Underground and elevated routes are combined and an underground method, without station construction in the initial opening stage on the southern route, is planned for saving around US$ 20 million
2) Financial impact to railway operator	Connection between City Center (Monas) and Suburban Bus-Terminal (Lebak Bulus) is planned at the initial opening stage with expected passenger demand by 350,000 passenger/day in 2015
3) Environmental assessment including aesthetics and climate condition	City center route is required by underground for aesthetic protection and suburban route is also required by underground due to difficulty of elevated method on the existing narrow road and land acquisition
4) Synergy effect by joint development of railway and adjacent area with positive land valuation	Value hike of adjacent property is expected after opening of the underground MRT Station along main axis roads

5. Conclusion

Jakarta MRT Project will be the first urban railway in Indonesia to use the combination of underground and elevated routes. For comparison of Jakarta MRT Project, the analysis study on the urban railway development examples in Japan has been made and it has been summarized that the following main evaluation factors shall be considered and assessed for the route selection by using either elevated or underground method:

1) Cost comparison including land acquisition
2) Financial impact to railway operator
3) Environmental assessment including aesthetics and climate condition
4) Synergy effect by joint development of railway and adjacent area with positive land valuation

Suitableness of route selection by underground and elevated method for Jakarta MRT Project is verified by the above evaluation factors, which is the conclusion of comparison study between Jakarta MRT Project and the urban railway development examples in Japan. Similar comparison study in other Asian countries, such as Singapore, Hong Kong, Kuala Lumpur or Bangkok, will be further analyzed for reference.

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f. Sapporo City Government, Transport Bureau, Project Management Division Officer: Mr. KAMI Kenji
g. Sapporo City Government, Transport Bureau, Rolling Stock Division Officer: Mr. OKABE Hiroshi
h. Sendai City Government, Transport Bureau, Construction Division
i. Tokyo Metro Company, Transport Market Division, Passenger Section: Mr. UEMURA Jyun
j. Tokyo Metropolitan Government, Road Construction Department, Railway Division, Railway Planning Section: Mr. OKU Tomomi, Mr. TERAJIMA Seiji

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