World

PROJECT STUDY ON RAILWAY OPERATION AND MAINTENANCE

FINAL REPORT

SUMMARY

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Japan International Cooperation Agency (JICA)

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Oriental Consultants Global Co., Ltd.
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PROJECT STUDY ON RAILWAY OPERATION AND MAINTENANCE
FINAL REPORT SUMMARY

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ABBREVIATION

AFC	Automatic Fare Collection
ARL	Airport Rail Link
ATC	Automatic Train Control
ATO	Automatic Train Operation
BEM	Bangkok Expressway and Metro Public Company Limited
BRT	Bus Rapid Transit
BTS	Bangkok Mass Transit System Public Company Limited
DD	Detail Design
DOTr	Department of Transportation
DRT	Department of Rail Transport <Thailand>
ECM	Egyptian Company for Metro
FS	Feasibility Study
GC	General Consultant
H. E.	Human Error
HURC1	Ho Chi Minh City Urban Railway Company Line 1
JICA	Japan International Cooperation Agency
JTT	Japan Transportation Technology
KCI	Kereta Commuter Indonesia
KPI	Key Performance Indicator
MAUR	Management Authority for Urban Railways
MHSC	Mitsubishi Hitachi Sumitomo Consortium
MMRCL	Mumbai metro rail corporation
MP	Master Plan
MRT	Mass Rapid Transit
MRTA	Mass Rapid Transit Authority of Thailand
MRTJ	Mass Rapid Transit Jakarta
MTJV	MTJV (Thailand) Co.,Ltd
NAT	National Authority for Tunnels
O&M	Operation and Maintenance
OCC	Operation Control Center
ODA	Official Development Assistance
OJT	On-the-Job Training
PDCA	Plan Do Check Action
PM	Person-Month
PPP	Public Private Partnership
PSD	Platform Screen Door
PSO	Public Service Obligation
PT.KCJ	PT KAI Commuter Jabodetabek
SRT	State Railway of Thailand
SRTET	SRT Electrified Train Co., Ltd
TA	Technical Assistance
TC	Technical Cooperation
TISS	Toshiba Infrastructure Systems & Solutions Corporation
TOR	Terms of Reference

Chapter 1 Outline of the Project Study

1.1 Outline

1.1.1 Background and Purpose

(1) Research Background

JICA projects have provided support for railway development mainly in urban areas of Asian countries. These countries have a continuing great need for the high-quality railway construction assistance Japan provides. Future JICA projects will also accurately identify these needs and promptly put together projects for assistance in safely and reliably conducting operations and maintenance (O&M) of those railways. Therefore, it is necessary to organize information on Japan's experience in railway operators, lessons learned from past JICA projects, and O&M cases of railroad operators in other countries and other sectors, and to utilize this information for future project formation.

(2) Purpose

The purpose of this project study is twofold.

- To produce a handbook and pamphlet that contribute to raising the quality of railway O&M organization-building support in future JICA projects (including future recommendations)
- Consider possibilities for maintenance projects (primarily for civil structures and tracks) that are customized to developing countries' needs and utilize assets such as Japanese technology and knowledge

1.1.2 Summary Report Structure

The report's composition is provided below. Chapters 2 and 3 contain important basic information when considering O&M organization-building support. Chapter 4 covers possibilities for technical support customized to the needs of developing countries, which is one more purpose of the research.

Chapter 1 Outline of the Project Study

Contains the research's background and purpose and how to use the results.

Chapter 2 Basic Knowledge

The chapter covers the necessary commercial and technical basic knowledge for O&M considerations. These items are covered separately according to the "Overview of O&M Studies in JICA Projects." At every stage of studies, surveyors checked this general overview for what kind of considerations to carry out, allowing the reader to check the details of each item on the following explanatory pages. The chapter also organizes basic information on O&M cases both in Japan and abroad, as well as in other sectors. The cases on these pages are presented as a reference source about JICA projects so that the reader can gain knowledge concerning a variety of O&M efforts.

Chapter 3 Past Support Projects and Future Assistance

This chapter contains details on support for past and ongoing JICA projects, as well as the accomplishments and challenges arising from support projects to be kept in mind for assistance provided in the future. and checklists for standard O&M support projects and support framework is provided to do successfully in future feasibility studies, approaches to project assessments, etc.

Chapter 4　Overseas Expansion of O&M

With a focus on Southeast Asian countries, this chapter contains railway O&M study results such as their current state, challenges, and needs, as well as the direction of technical assistance to maintain safe and reliable railway operations for key urban transportation networks. The chapter then provides observations on how support for civil structure maintenance will develop.

1.1.3 Results of Project study

(1) Overall Structure of the Results

One purpose of the research is to produce a handbook and pamphlet that contribute to raising the quality of project creation and implementation as it pertains to O&M implementation. Figure 1-1 provides the essentials for the handbook and pamphlet. The handbook covers all of requirements 1) through 6) in the figure, while the pamphlet provides a clear and concise summary covering 1) and 2). Supplementary explanations of approaches, specific cases, and other matters that could not be written in the summary report or handbook due to paper space appear in the final report, which readers can reference in case of any questions concerning these points.

The important key phrase to embodying the requirements listed in Figure 1-1 is "general O&M idea to consider." Defining this would likely impact the entire study.

Section 2.1, found in the following chapter, provides three items as an initial definition of "O&M framework to consider" in the research as "considerations and preparations to make for reliable, sustainable O&M projects." The section includes basic knowledge and real-world cases to provide an explanation of these three items and recommendations for future assistance.

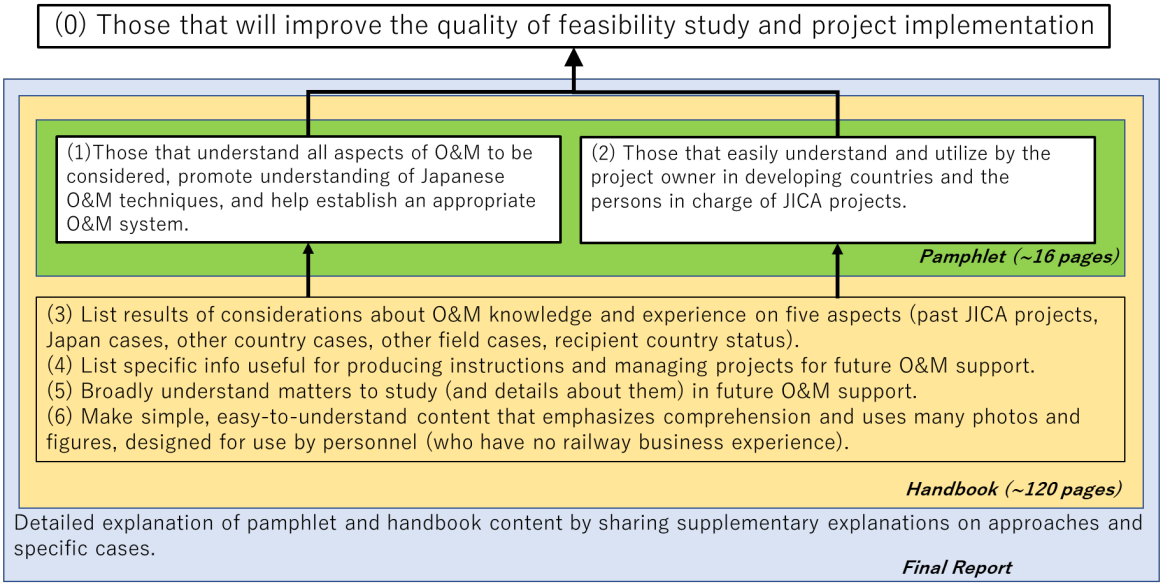


Figure 1-1　Overall structure of the Results

(2) The Handbook's Structure

The handbook providing the main results of the research is structured into four chapters as shown in Figure 1-2: 1) Basic Knowledge, 2) O&M Case Studies, 3) Past Projects, and 4) Future Projects. Descriptions of each chapter's contents are below. The report is organized in the same format for easy reference.

① Basic Knowledge follows the "Overview of O&M Studies in JICA Projects" in the Outline to itemize the basic commercial and technical knowledge required to support reliable and sustainable

O&M. The technical requirements relate not only to the technical specifications of railway systems, but also explanations of matters to be considered in each technical field up until the time the recipient country can perform O&M independently.

② O&M Case Studies presents basic information on real-world O&M cases in both Japan and abroad, as well as other sectors. Each page has been written so the reader can reference JICA projects and gain knowledge on various O&M efforts.

③ Past Projects contains lists of supported details and descriptions concerning past and ongoing JICA projects. This section also provides knowledge concerning both the accomplishments and challenges resulting from these projects, to be kept in mind for assistance provided in the future.

④ Future Projects provides standard O&M plans and support plans for future use, as well as checklists for support details and key points for consideration during the O&M support implementation stage. Lastly, this section adds observations pertaining to future overseas expansion in the field of infrastructure maintenance.

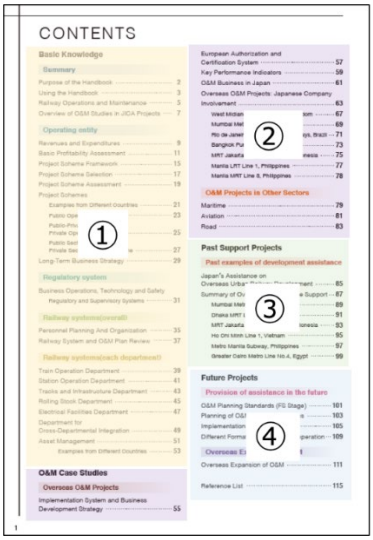


Figure 1-2 Handbook Structure

1.2. Project Implementation Plan Overview

1.2.1. Overall Schedule of Project

Figure 1-3 shows the overall schedule of project. Below are descriptions of the primary activities.

(1) Produce report, convene and deliberate at review committee, conduct seminar for railway personnel from Japan and abroad

(2) Organize basic knowledge of railway O&M

(3) Collect and organize information on O&M in railways and other industries in Japan and abroad, organize accomplishments and challenges in past JICA projects concerning railway O&M, and consider possibilities for overseas expansion of maintenance businesses (including trips to sites)

(4) Compile recommendations for future JICA projects

(5) Produce handbook and pamphlet and deliver printed materials

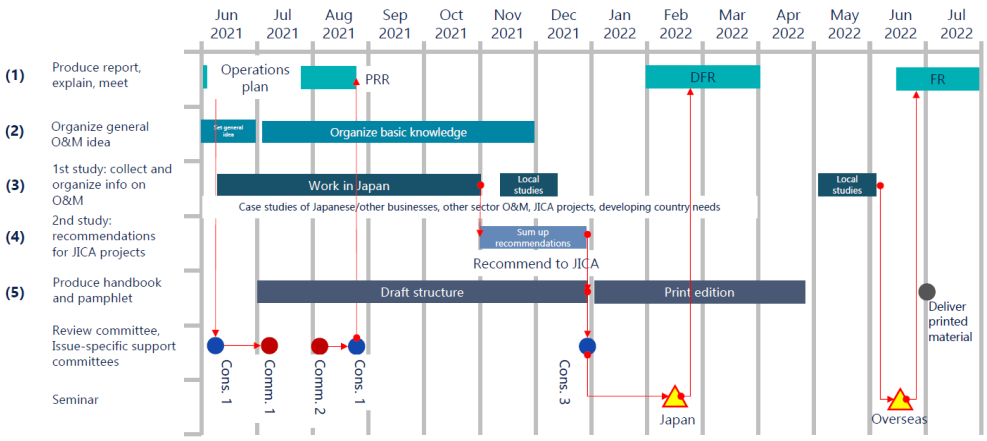


Figure 1-3 Flow Chart of the Implementation Plan

1.2.2. Primary Activities Overview

The major tasks (2) and (3) in 1.2.1 of the overall project study will be described.

First, regarding the organization of the O&M in general and basic knowledge, the necessary framework for proceeding with considerations, as shown by Figure 1-4, shall be defined, and the white areas in the figure under "specific items to consider" shall be explored and explained.

In addition, the following information concerning operation (3) was collected.

- Operating status, organizational structure, number of personnel, etc. of six Japanese subway operators
- O&M cases implemented by four global railway operators in other countries
- Project schemes, financial condition, etc. relating to O&M in six countries
- O&M cases in other sectors (seaports, airports, roads)
- Six cases of railway construction support in past and ongoing JICA projects

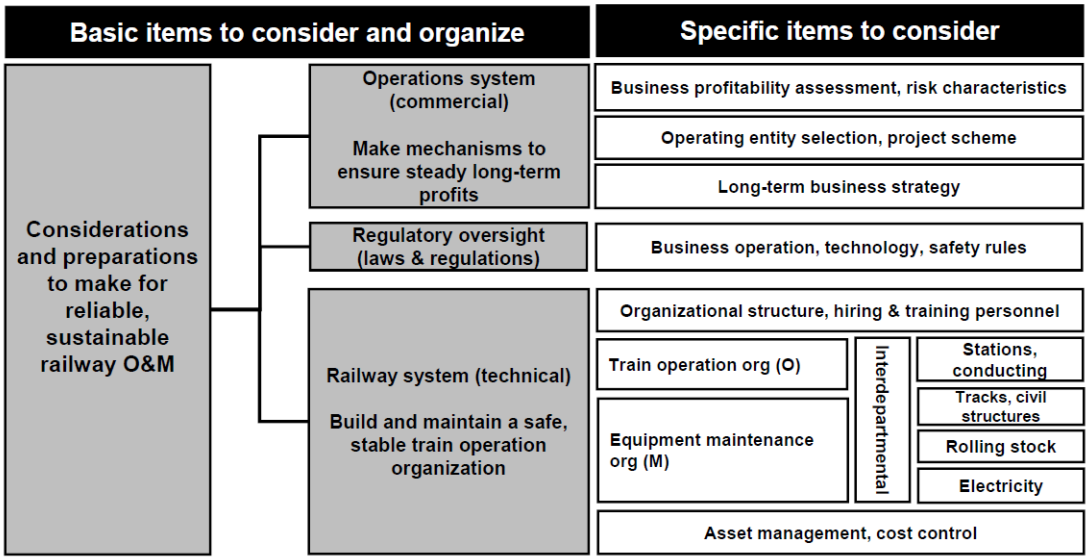


Figure 1-4 Items to consider for O&M

Chapter 2 Basic Knowledge

2.1 Overview of O&M studies in JICA projects (Handbook P5-P8)

It goes without saying that the operation of urban railways that support social infrastructure absolutely must maintain their reliability for a long period of time, not only when they first open. For that purpose, three items, as shown by Figure 2-1, were stipulated as conditions that demonstrate, in as comprehensive a manner as possible, the requirements for preparing reliable and sustainable railway O&M.

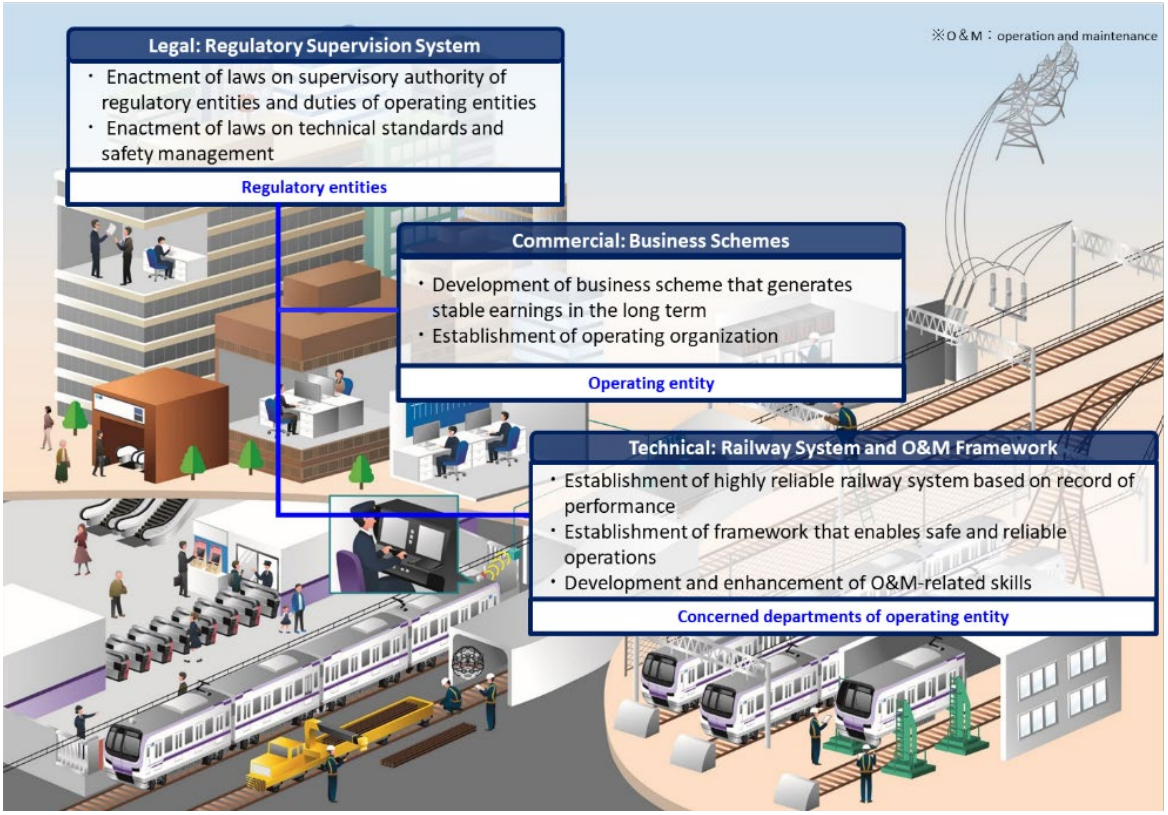


Figure 2-1 Three Necessary Elements for the O&M of Reliable and Sustainable Urban Railways

Figure 2-2 segmentizes the three items extracted from Figure 2-1 and provides a general idea by adding a temporal axis according to JICA project progress. The upper part of the figure contains commercial and regulatory system considerations, while the lower part contains technical considerations. The following sections follow the flow of this figure to list commercial, regulatory, and technical items for consideration.

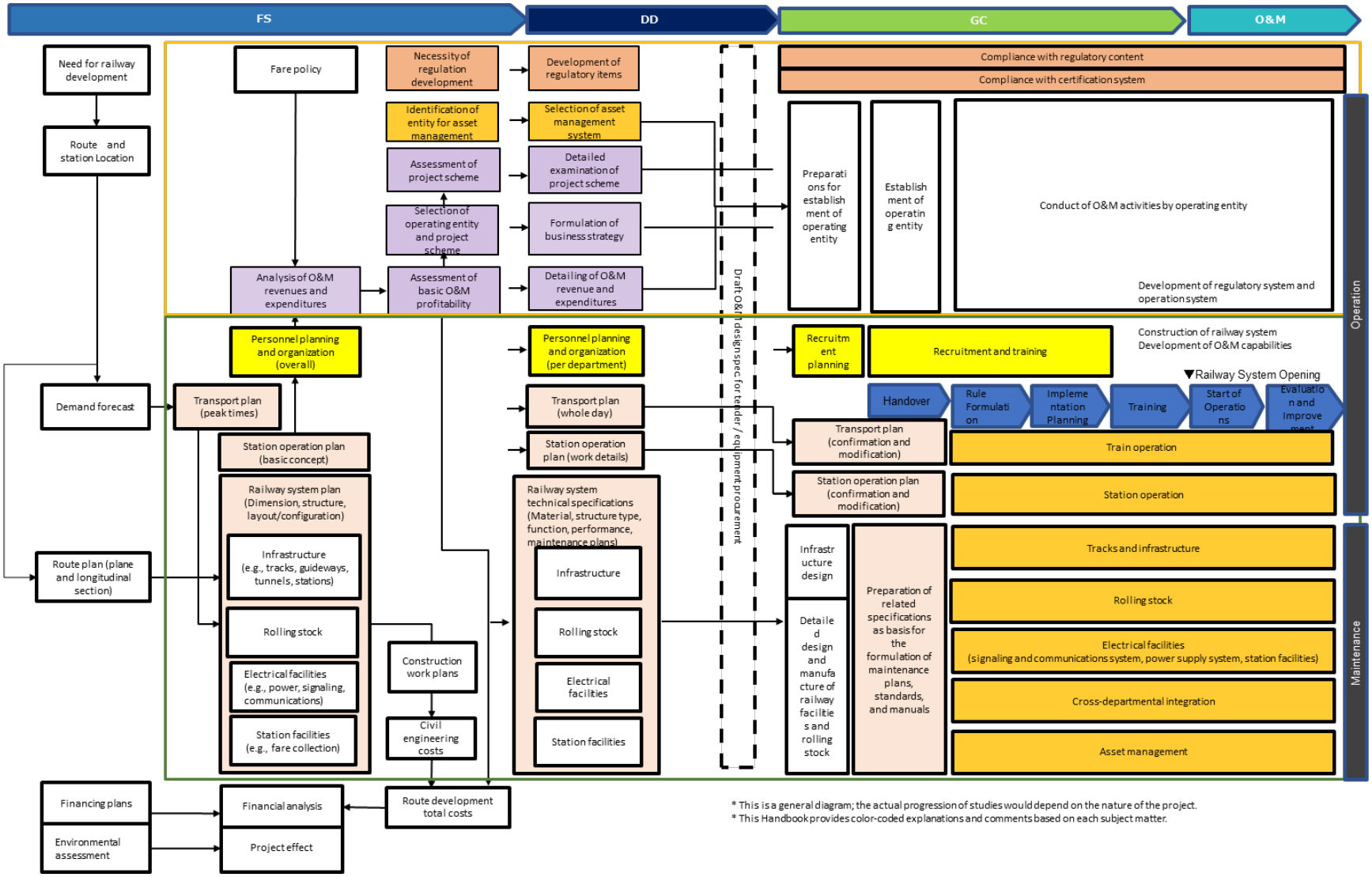


Figure 2-2 Overview of O&M Studies in JICA Projects

2.2 O&M Body

This section explains the process to study O&M body as part of "three elements for reliable and sustainable railway operations".

[Step 1] Revenue & expenditure, basic profitability, risk characteristics, and profitability assessment

[Step 2] Project scheme framework

[Step 3] Project scheme (indicating the relationship between the authority & the O&M entity)

[Step 4] Long-Term Business Strategy

Below is how to proceed with considerations according to the process.

2.2.1 Revenue & expenditure, basic profitability, risk characteristics, and profitability assessment (Handbook P9-P14)

(1) Basic Profitability Assessment Flow

Revenue & Expenditure Structure Analyzing the revenue and expenditure structure is the starting point of evaluating basic profitability; it starts at the project formulation stage (FS stage) and should be re-examined at every succeeding project stage.

[FS Stage] Projections of revenues and expenditures of the operating entity based on a preliminary project scheme and planned features / figures

[DD Stage] Revisions and enhancements of the revenues and expenditures according to the results of the detailed designs

[GC Stage] Finalize the demand, revenue and expenditures as part of the business plan at the preopening stage.

Demand forecasts tend to be overestimated compared to actual ridership. Demand forecasts, ridership, and fare revenue estimates are better examined using conservative scenarios and setting a demand retention rate or ramp-up factor based on case studies.

Assessment Flow Basic profitability should be evaluated based on the revenue and expenditure structure established at the FS stage. Project stakeholders should carefully review financial performance, considering the profit and risk characteristics of urban railways. Basic profitability can be better understood in the years after the start of railway operations when the fare revenue begins to exceed the O&M costs.

Policy Perspective The government should be responsible for railway network development, especially since the backbone or trunk line will be a future source of revenue generation and eventually finance subsequent investments in transport network expansion. As such, urban railway development should start with the lines that show good profitability prospects. Urban railway construction is mainly financed through public funding. Subsidies for capital and operating expenditures are drawn from the increased central and local government tax revenues from urban railways.

(2) Profit and Risk Characteristics

Profit Characteristics of Urban Railways Urban railways are capital-intensive and network-based undertakings. Railways are unlikely to profit in the short run if it exists only as a single line. As railway construction is a capital-intensive venture; and fare revenues are unlikely to recover the capital expenditures.

Risk Characteristics of Urban Railways Railway O&M have varieties of risks, which typically includes delayed opening risk, demand/ridership risk, fare setting risk, O&M cost risk, capital shortfall risk, government budget risk, etc.

(3) Profitability Assessment

Fundamental Assessment Basic profitability is assessed by examining the balance of revenues and expenditures, which is essentially the net fare revenues and O&M costs computed over the project period. Additionally, commercial business revenues and other items, such as subsidies, are factored into the revenue calculations, whereas project cost items like taxes (as in the case of private sector O&M) are incorporated in expenditure side of calculations.

Classification by Trends Basic profitability can be classified according to the resulting changes in the balance between the fare revenue and O&M costs. The recovery of the O&M costs through fare revenue is essential to sustain business operations, particularly in countries where the government has limited capabilities to provide financial support.

Classification by single year performance Farebox recovery ratio (FBR), defined as the ratio of fare revenue to O&M costs, indicates the single year performance. If FBR is below 1.0, fare revenue cannot cover O&M costs; and subsidies are needed for operation, replacement, and reinvestment of the railway system. Even if EBR exceeds 1.0, fare revenue can cover the O&M costs; but subsidies may still be needed for replacement and reinvestment costs.

2.2.2 Project Scheme Framework and Selection (Handbook P15-P22)

(1) Project Scheme Framework

Various project schemes can be compared if basic profitability reaches the threshold.

Three (3) parameters can be considered in selecting a project scheme: (1) asset development; (2) demand risk; and (3) operating entity. The general advantages and disadvantages of each project scheme are shown on the below table. Important considerations when selecting a viable project scheme are as follows:

- In determining the financial framework for an urban railway, risk sharing and the scale of financial burden should be confirmed. Additionally, the degree of efficiency that the private sector can achieve should be very carefully considered.
- Other factors include: requirements for additional government subsidy to fill the viability gap and attract the private sector; intention to standardize/ integrate the different railway systems in the network; and government risks in the event of bankruptcy or other financial inabilities of the private operating entity.
- Decision makers should maximize the advantages and minimize the disadvantages of the preferred option by understanding the characteristics of each financial framework.

Table 2-1 Summary of Advantages and Disadvantages per Option

Parameter	Option	Advantages	Disadvantages
① Asset development	Full government funding	Easy access to low interest loans offered by international donors Easy fund management by the public sector Simple investment structure	Limits to budgeting and borrowing Numerous decision-making processes
	Some private sector funding	Potential to accelerate railway network development Potential to reduce government borrowing Risk transfer to the private sector	High initial investment costs Difficulty in controlling railway network development
② Demand risk	Net cost	Independent pursuit of profits by the private sector	Considerable demand risks Public sector difficulty in exercising control
	Gross cost	Easier and sustainable revenue generation by private sector enterprises	Additional contract management and business monitoring capabilities required of the government
③ Operating entity	Operated by a public sector entity	Sustainable operations without heavy dependence on profits Secured service levels regardless of corporate situations	Business knowledge required of the public sector Possibility of underperformance due to budget constraints Possibility of salary and personnel systems to become rigid
	Operated by a private sector entity	Easy implementation of performance-based salary structures and personnel evaluation	Higher operating costs when profit and taxes are accounted for (if efficiency level is the same in both public and private sectors)

(2) Project Scheme Assessment

With the key assumption that the O& M performance of the private and public sectors are the same, the analysis compares the lifecycle cost (LCC) or long-term financial burden of the public sector in each financial framework. This is calculated by subtracting the present revenue value from the present expenditure value.

Initial cost reduction for government In the case of PPP, the government can reduce its initial investment burden, as the private sector bears part of the initial costs. On the other hand, if basic profitability is low, government subsidies are needed to help the private sector. Therefore, compared to public investment schemes, PPPs tend to increase government financial burdens over the project life.

Advantage of public sector investment with public operations In the case of the vertical separation, the private sector contributes part of the initial investment, while additional financial costs are shouldered by the public sector. Also, the private sector requires profits from business activities in the areas of railway operations. Therefore, unless the private sector achieves operational efficiency, Public Sector Investment with Public Operations is considered more advantageous than PPP.

Efficiency improvements by private sector In order to bridge the gap between public operations and the government's financial burden under PPP arrangements, the private sector has to achieve efficiencies at both the construction and operational stages. However, there is little evidence to quantify the difference and generalize the performance of the public and private sectors.

Project scheme evaluation Given the capital-intensive nature of urban railways with a variety of risks in construction and operations, the high financial costs to the private sector tend to require high returns. For this reason, PPP is generally difficult to pursue in the urban railway sector, particularly without sufficient financial support from the government.

Aside from understanding the likely extent of the financial burden on the public sector, the desired policy outcomes are also an important consideration when determining the preferred scheme.

(3) Project Schemes: Examples from Different Countries

A variety of project schemes have been studied and implemented in different countries. The experiences of identifying and implementing these project schemes provide invaluable lessons in determining viable project schemes for future railway projects.

Public investment with public operations model Cities introducing urban railways for the first time in their localities usually opt for a public investment model involving public sector as the operating entity. Such is the case of Jakarta and Ho Chi Minh. It is seen as a rational choice from a long-term perspective, as it allows the public sector to build its own O&M capabilities. Eventually, cities can then contract out O&M activities to private operating entities.

Other Options Some cities opted for a PPP model even for initial urban railway projects in their localities. One such case is in Bangkok where the Ministry of Finance understood the viability of using a PPP-based scheme as the agency also manages their public debt. On the other hand, some cities prefer engagements wherein the government bears the initial investment and having a private sector partner for O&M. Such option has been done in cities like Manila. There is no single project scheme that perfectly applies to every urban railway project context. Corresponding forms of O&M engagements are designed on a project-to-project basis depending on different factors such as the scale of business activities, government policies, the investment and loan horizons, and the willingness of actors to participate in the urban railway O&M activities.

Vertical separation model In the vertical separation model, financial structures are normally decided on a case-to case basis. Considerations include how much the private sector pays for access charges to the government. Furthermore, how much subsidies can be provided by government, for instance as a portion of the construction or operating costs for the urban railway system.

Less emphasis on private sector's role Many PPP projects that are structured "BOT-type"

modalities in the urban railway sector rely on the private sector for financing initial investments have experienced difficulties in operationalization. This can usually occur when the railway network has yet to be fully established. In such case, appropriate risk allocation between the Public and private sectors should be closely considered, as in the cases of Kaohsiung and Bangkok.

2.2.3 Project schemes (Handbook P23-P28)

(1) Public Operator

1) Public Sector Investment/Public Operator Scheme (Jakarta MRT)

Vertical Integration This applies when the public sector entity is responsible for both construction and operations. While generally difficult, the private sector can be amenable to this scheme in some cases. The government grants rights to the private entity to build and operate the system, including the development of civil structures and procurement of rolling stock and E&M systems. The private entity is also engaged in O&M after commissioning. The business entity covers O&M-related costs through both fare and non-fare revenues.

2) Private Investment/Public Operator Scheme (Manila MRT Line 3)

Build-Lease-Transfer The business entity with a build-lease-transfer (BLT) agreement with the government is responsible for construction of civil works, procurement of rolling stock and E&M systems, and leasing of facilities to the government after the railway system is commissioned to operate. Operations is performed by the government or outsourced to an O&M contractor separate from the BLT partner. Maintenance may likewise be outsourced to private sector. The government pays lease fees to the business entity during the contract period.

(2) PPP/Private Operator

1) PPP/Net Cost Scheme (Bangkok Blue Line)

Vertical Separation: Build-Operate-Transfer (Net Cost Scheme) The government is responsible for infrastructure development by assigning contractors for the majority of civil works and track works. The rolling stock and E&M systems are procured by a business entity with a build-operate-transfer (BOT) contract with the government. The business entity contracted by the government subsequently operates the facilities for a certain period after the contract period ends, the facilities are then transferred to the government after concession period. Basically, the government does not recover the infrastructure investments from the fare revenue as the rail system, in effect, is received by the business entity. For this reason, the business entity virtually pays for facility access charges to the government through its own investment after the service commencement.

2) PPP/Gross Cost Scheme (Bangkok Purple Line)

Vertical Separation: BTO (Gross Cost Scheme) The government was responsible for infrastructure development, including majority of the civil works and track works, by assigning contractors. The rolling stock and E&M systems were then procured by a business entity with a build-transfer-operate (BTO) contract with the government. The government undertook the infrastructure development and directly receives the fare revenue. The business entity does not bear any of the ridership risks as the entity receives predetermined service fees with the amount of O&M costs plus an appropriate profit share.

(3) Public Sector Investment/Private Sector Operator

1) Public Investment/Net Cost Scheme (Melbourne Subway)

Public Sector Investment/Net Cost Scheme The government is responsible for all construction and procurement activities. The public sector carries out civil works as well as procurement of rolling stock and E&M systems. The private sector operator carries out the O&M after railway opening and uses fare and non-fare revenues to cover all the related costs of operation and maintenance. Subsidy provisions for O&M can be considered depending on the balance between revenues and expenditures.

2) Examples of Public Sector Investment/Gross Cost Scheme

The Metro Manila Subway and other projects aim to introduce this type of scheme. The Bangkok Mass Transit System (BTS) initially chose the BOT/Net Cost Scheme but adopted the Public Investment/Gross Cost Method for the extension sections.

Public Sector Investment/Gross Cost Scheme

The government is responsible for construction and procurement activities. The public sector undertakes the civil works and procurements of the rolling stock and E&M systems. The private sector operator does not bear any ridership risks as the entity receives pre-determined service fee with the amount of O&M costs plus an appropriate profit.

2.2.4 Long-Term Business Strategy (Handbook P29-P30)

(1) Development of Business Strategy

A business strategy is typically developed during the design stage. It is based on both the project scheme identified at the FS stage and the business case prepared during the DD stage. After the type of operating entity is established at the GC (construction) stage, a more detailed business strategy is formulated at the pre-opening stages. During the operational stage, the operating entity should review the business strategy from time to time to reflect changes in the socio-economic conditions, trends in the external business environment, and technological innovations, among other factors.

(2) Development of Management Plan (Action Plan)

All organizations need a management plan based on its business strategy. New organizations in the urban railway sector requires professional advice from industry experts.

At the project implementation stages, project stakeholders have the tendency to direct its focus mainly on construction works rather than pay due attention to the operation and maintenance aspects of the system. Additionally, it is hard to anticipate any practical business strategies other than "safe and reliable transport" if the entity does not have actual O&M experience. Such is the case if the railway to be developed is the first urban railway line for the city.

Ambitious business development concepts such as non-fare commercial businesses, transit-oriented development (TOD), and technological innovations have been promoted for urban railways. However, these remain impractical, or in some instances unattainable, without sufficient organizational, human resource and financial capacities.

Operating entities need to envisage business strategies according to the level of maturity of the local socio-economy, railway industry, and existing railway organizations. While referring to examples of structures and formulation procedures, the management of the operating entities should refrain from conveniently mimicking and applying the plans and strategies of the other operators.

As the assistance for urban railway O&M in this study focuses on the period until 5 years after opening of the system, JICA and consultants should particularly help develop the practical business strategies.

With respect to the development of long-term business strategies, JICA may initiate some sorts of studies and/or technical assistance programs according to the particular needs identified in each project.

2.3 Regulatory and Supervisory Systems (Handbook P31-P34)

This section addresses how to proceed with considerations of regulatory systems within the "Three Necessary Elements for the O&M of Reliable and Sustainable Urban Railways."

(1) Overview of Considerations

As shown in Figure 2-3, the workflow for considering railway O&M regulations begins with the nature of the country's regulations, and it must confirm how roles and responsibilities are divided among railway industry participants (such as regulatory bodies, railway operators, and manufacturers). In Japan, responsibility for railway system adequacy assessments (only for certified railway operators) and applications, as well as administrative and technical aspects, lies with railway operators across the board (blue part of Figure 2-3). Meanwhile, under the European approach, the division of roles and responsibilities among relevant parties is vastly different. A point one must keep in mind is the large difference in the amount of work required for operating entities' business permits as well as the licensing procedures for assessments of adequacy under railway system laws and regulations. Since the roles also differ between projects depending on the recipient country, one must confirm how to divide roles in railway construction, as well whether to adopt the Japanese or European approach or the recipient country's own original approach.

Upon confirming this division of roles and responsibilities, one must next consider specific regulatory details. During these considerations, one would refer to items in Japanese regulations (business operation basics, railway technology matters, safety maintenance matters, passenger sales matters [fares, etc.], railway personnel matters, etc.), but since one cannot apply cases from Japan to another country without adjustment, one would consider the necessity of regulatory items while making comparisons with Japan.

Following this workflow, in the end, the operating entity must write in-house rules based on the regulations enacted by the country. As an example of writing in-house rules based on the applicable laws and regulations, Figure 2-4 provides an example regulatory system for reporting accidents in Japan. The in-house rules are divided into two stages: common in-house rules that should be written across departments, and operating rules formulated by each technical department.

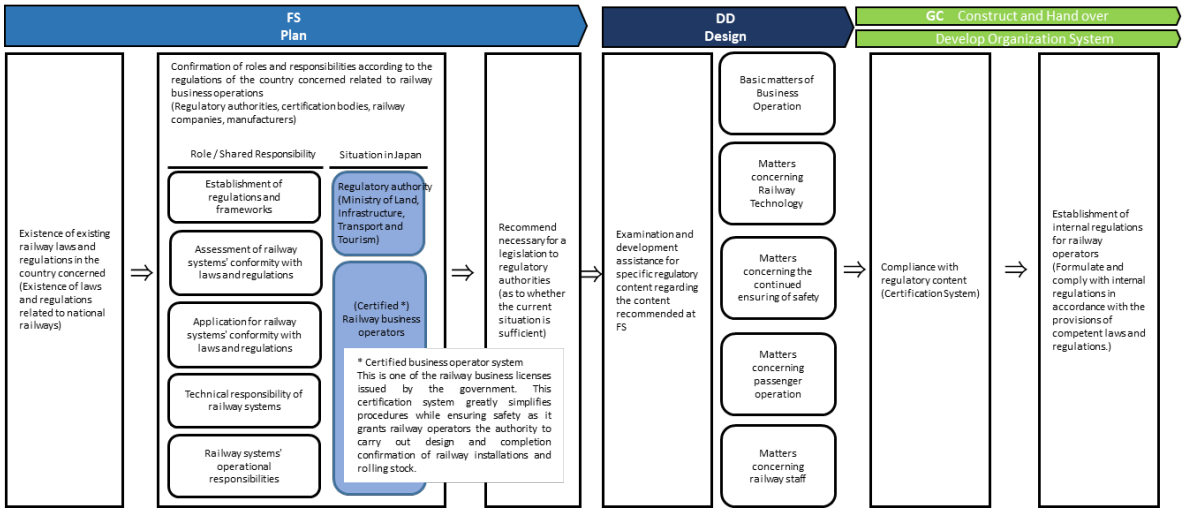


Figure 2-3 Development Flow of Railway O&M-Related Regulations

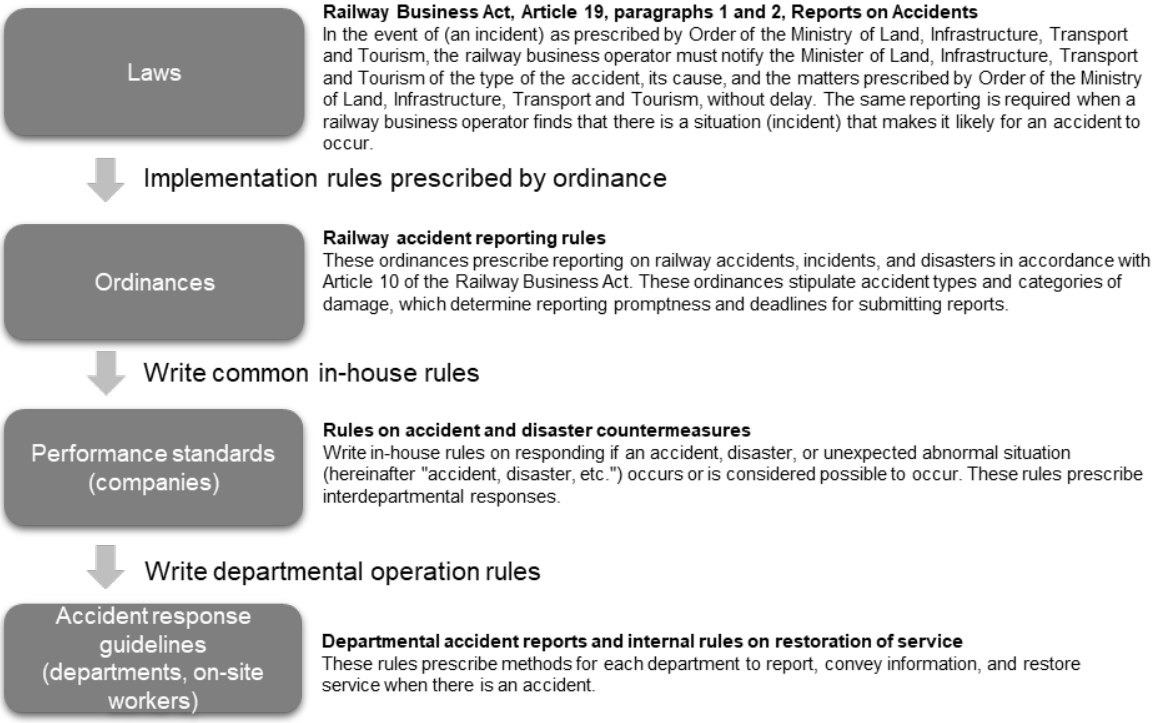


Figure 2-4 Relationship Between Laws and In-house Rules

2.4 Railway system

This section addresses how to proceed with considerations of railway systems within the "Three Necessary Elements for the O&M of Reliable and Sustainable Urban Railways."

2.4.1 Personnel Planning and Organization (Handbook P35-P36)

(1) Basic Concept

An O&M entity is expected to have low profits from its establishment until the retention of passengers after its railway system opening. Since preparations and operations at the onset require a limited number of personnel, the gradual expansion of manpower and the organization as a whole is advisable. Please refer to the full version for each department of the O&M organization and their function.

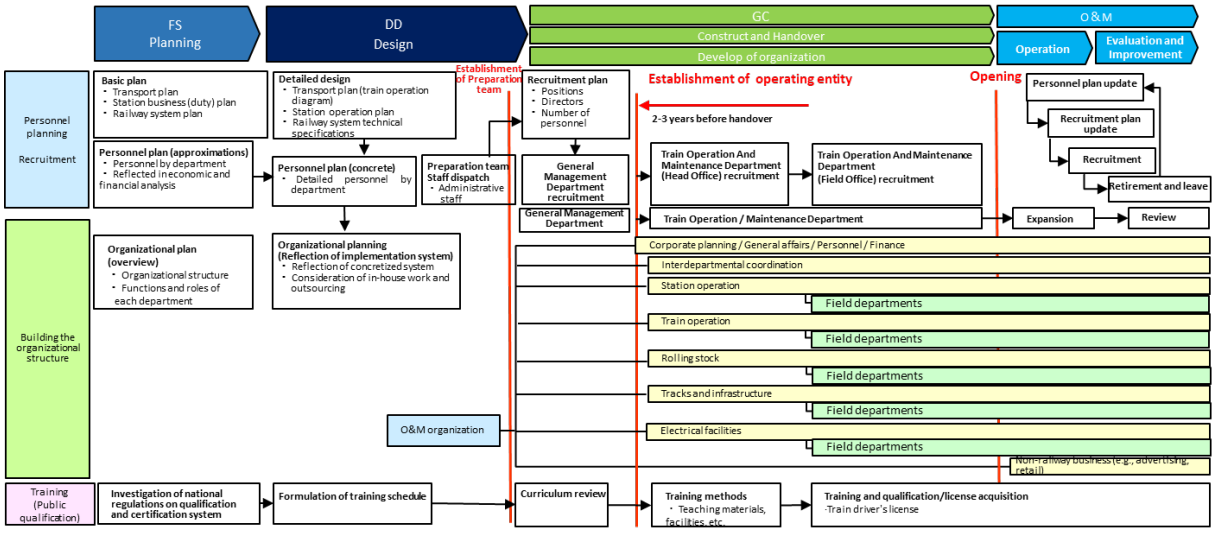


Figure 2-5 Flow Of O&M Personnel Planning And Organizational Structure Construction

(2) Points for Consideration

1) Personnel planning and recruitment

Personnel planning for O&M organization is the basis for a healthy and sustainable urban railway. Even as work efficiency improves with the introduction of new technology, it is essential for personnel to accumulate and improve their work experience and steadily pass it on to future generations. To this end, it is important to plan for personnel from a long-term perspective, and to recruit and train personnel.

2) Organizational Structure Development

It is necessary to confirm what role and support the implementing country requires for urban railway, and to be careful not to establish a huge O&M organization with a large number of personnel from the early stages of opening, when revenues are low.

3) Training

In O&M of urban railway, it is necessary to obtain licenses and public qualifications required by related laws and regulations for each field before the start of operation. In particular, train operation licenses require classroom learning and simulator training, as well as test runs using actual equipment during the limited period between the handover of equipment and the start of operations.

In the FS stage, It is necessary to introduce other examples of the personnel development and timeframe required until opening, and to gain understanding from the relevant organizations in the implementing country to prepare opening.In the DD stage,necessary timeframes for personnel should be developed, and after the GC phase, formulating detailed methods for personnel should be developed. Coordination is essential to avoid overlaps or shortages in contractor-provided training.

2.4.2 Railway System and O&M Plan Review (Handbook P37-P38)

(1) Development Flow for Railway System and O&M Planning

As Figure 2-6 shows, O&M planning considerations start with the required transport capacity, based on the demand forecast that was considered in the basic policy for route development, followed by gradual implementation of the O&M plan while coordinating closely with the railway system plan. In the FS stage, a basic plan is formulated as required for the estimated business costs, and in the DD stage, specifications are finalized for the various equipment, as well as the operation and maintenance plans, required for equipment design and production. Equipment procurement is based on those specifications. From GC onward, after creating specific designs and producing, the railway system is constructed. Then, detailed as-built drawings are prepared, noting exactly how to operate the constructed railway system. These drawings are handed over to the operating entity. (For what happens after handover, refer to each technical department's explanation.)

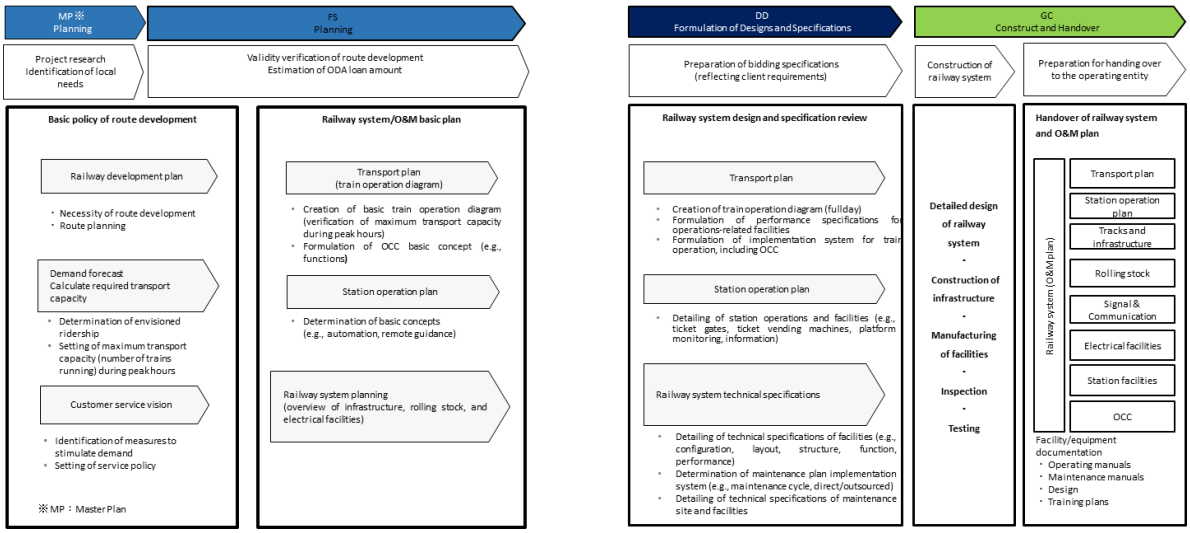


Figure 2-6 Development Flow for Railway System and O&M Planning

2.4.3 Train Operation Department (Handbook P39-P40)

(1) Basic Concept

Put simply, the role of an operating department within a train operation organization is to reliably carry out the plans that were built upon the transport plan (i.e., the timetable). In addition, the steps listed here will provide direction on technical support for urban railway construction projects for local counterparts during the GC phase in developing countries.

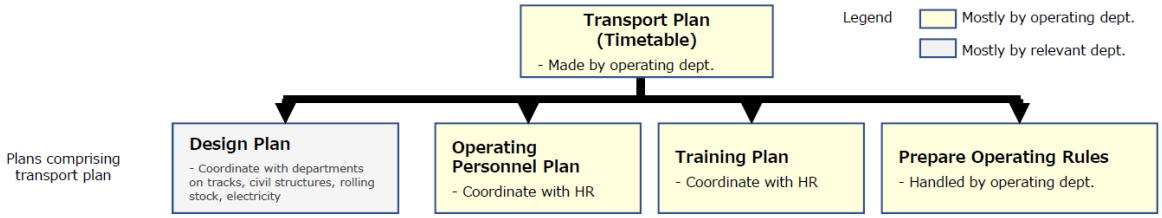


Figure 2-7 Transport Plan's Relationships with Other Plans

(2) Points for Consideration

1) Transport plan (train operation diagram)

After finalizing technical specifications for equipment, rolling stock, and so on up until DD, the operating department produces a train timetable reflecting the specifications. The timetable is accurate to the second. The timetable, highly precise on the practical operation level, is used when the railway opens.

2) Cooperation with maintenance departments

This involves arranging the necessary tools to implement the transport plan. Specifically, it applies to civil structures along the tracks, rolling stock, and electrical equipment. Relevant departments discuss and handle these matters.

3) Personnel planning and Training plan

This refers to the personnel plan providing the required staff to handle the tools mentioned in 2) above, as well as the training plan to provide the necessary knowledge and skills to properly handle said equipment.

4) Regulations and manuals

These items clarify the handling and relevant rules for the aforementioned tools (i.e., equipment and rolling stock). First, the operating rules are based on the relevant laws and regulations of the country where the rolling stock is operated. The rules are written to reflect the handling instructions and the specifications of the operating equipment as provided by the contractor during GC. After finalizing the regulations, the manuals are produced according to the handling instructions provided by the contractor.

After the line opens, if there are changes to the tool specifications or the introduction of a new system, regulations and manuals must be revised to handle them. If the regulations and manuals are changed, this information must be provided accurately to relevant departments.

The aforementioned plans for the operations department must of course be fully prepared prior to the line's opening (i.e., before implementation), and if defects or flaws are confirmed via assessment after opening (i.e., after implementation), improvements must be made and reflected in the next plan. To that end, an organization that continuously follows the PDCA cycle by involving all relevant departments

within the company is essential to a reliable and sustainable train operation organization.

2.4.4 Station Operation Department (Handbook P41-P42)

(1) Basic Concept

A station provides front-line customer services, including ticket sales, security checks, platform safety checks, directions to passengers, and handling lost items. To that end, in addition to ensuring rider safety, it is important to provide station services that are convenient to users. As a quantitative method of measuring these things from a service provider point of view, the introduction of indicators, such as KPI related to passenger satisfaction, must be kept in mind when considering how to manage operations.

(2) Station Operation Workflows Until Opening

Station operation workflows are divided into four broad categories. Those workflows are shown in Figure 2-8.

- Station operation plan (external coordination: notification reporting to government authorities; internal coordination: medium- to long-term departmental plans, budget management, and creation of station service implementation organization)

- Regulations: manuals (to properly carry out operations)

- Station personnel assignments (personnel planning and division of duties)

- Operation of station equipment (equipment specifications and layout)

- Station operation plan

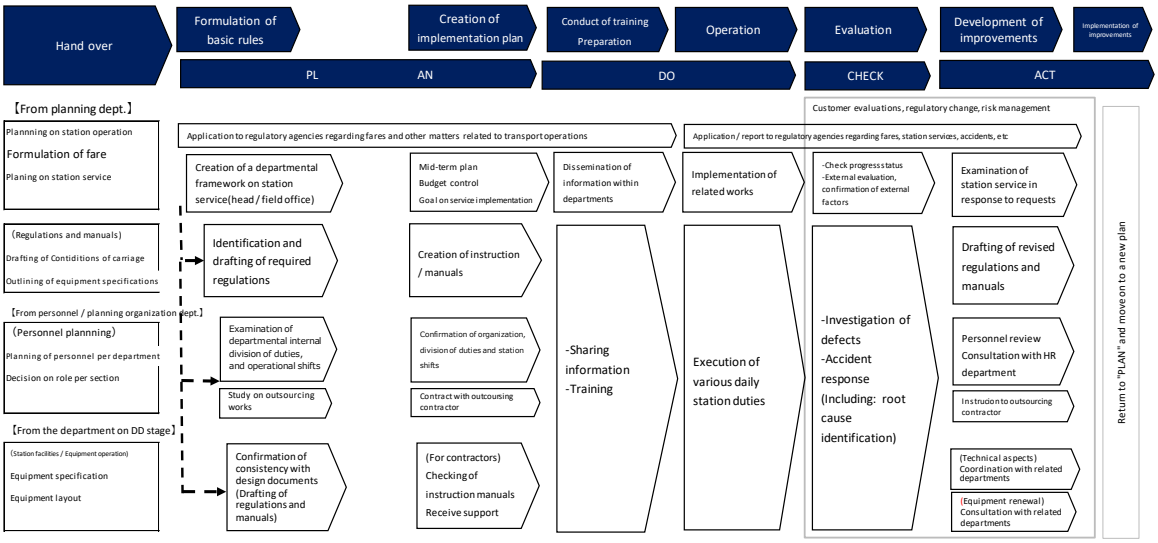


Figure 2-8 Overview of Station Operation Department Workflow

The various operations at the station must be properly carried out according to the prescribed rules. Regulations and manuals provide those exact rules. One of the most important of these regarding decision operations is the conditions of carriage. Important associated items that concern the management of station operations are instructions to station personnel, management of station revenues, as well as company rules and operating manuals pertaining to such matters as procedures at platforms. The content of these items must be laid out in advance to carry out operations.

Producing regulations and manuals requires both an understanding of the relationship with governing laws and regulations as well as a systematic comprehension of the relationship with the relevant company rules. The efficient, proper execution of station operations requires in-depth consideration of personnel placement and division of duties in the head office and each station department (including outsourcing agreements with business partners and other entities), and also requires training.

Personnel assignments are based on the estimated personnel plan and proposed organizational division until the DD stage, and shall be scrutinized from the GC stage onward. This involves the scrutiny of personnel assignments in terms of placing the required personnel to carry out operations and shifts for individual station duties, and adjustments must be made for staffing shortages until the line's opening. Furthermore, if operations are confirmed as or feared to be not functioning smoothly within a department, the HR department or other such organization must investigate the matter separately and revise personnel assignments or division of duties.

Regarding station facility operation, prior training shall be conducted upon confirming the detailed specifications of the facilities and equipment (i.e., station operations equipment, PSD, AFC, and related passenger equipment) so as to carry out station department operations unimpeded. If, in this case, a contractor produces an equipment manual, attention must be given to the need to confirm compatibility with actual operations. After the line opens, these processes shall continue, without interruption, to undergo revision by following the PDCA cycle. Especially when providing technical assistance to counterparts with no railway experience, it is crucial to provide continued support by properly informing counterparts about what exactly the prescribed rules mean as well as what kind of coordination is required in relevant areas.

2.4.5 Tracks and Infrastructure Department (Handbook P43-P44)

(1) Basic Concept

Railway structures made of steel and concrete cannot easily be demolished and rebuilt, so timely repairs and reinforcements need to be carried out so that they can maintain their functions. On the other hand, wears, failures, and irregularities on railway tracks directly affect the safety and comfort of passengers; as such, it is very important to regularly inspect the tracks more frequently than civil structures. The tracks should be refurbished after a certain period of time. Nonetheless, it is imperative to have regular maintenance cycles based on inspection results for both railway structures and tracks 。

(2) Points for Consideration

Figure 2-9 provides an overview of how to build and sustain a maintenance organization. Thorough inspections and confirmations of the different facilities and ancillary equipment should be carried out, especially during handover of the railway system. Design drawings, construction methods, and completion inspection results are important references for conducting proper maintenance.

（Plan）

Along with formulating how to carry out tasks in accordance with the division of duties and the laws and regulations, the plan establishes methods for procurement and asset management. It also provides items that must be followed when carrying out maintenance tasks, such as inspections and repairs. Next, a medium- to long-term plan covering general operations is formulated and a budget is appropriated. At the same time, an inspection plan and training plan are formulated, and then an organization to manage personnel and select suppliers is created.

（Do）

At the initial operational stage, training and technical support on facility/equipment handling is provided by the construction contractor and equipment suppliers. The necessary maintenance-related measures are implemented based on the inspection data. In the event of an accident or natural disaster, recovery is the first priority; as such, construction activities are planned to ensure this. Furthermore, it is necessary to regularly update and relay information on the condition of fixed assets in accordance with any improvement works carried out.

（Check）

Results of inspections and improvement works over the years should be analyzed to improve inspection and construction methods. Emergency management measures are likewise analyzed in the same manner. In relation to the organizational structure, regular internal audits by upper management and audits by relevant government agencies are done to ensure that duties are being properly carried out.

（Action）

If repairs are assessed as insufficient for a structure or component to function as per specifications, further improvement works are carried out: appropriate activities (e.g., assessment, work procedures, construction methods, inspection methods) are reviewed; manuals and regulations are revised; and necessary training is provided to thoroughly disseminate information updates and, in the case of accidents, prevent recurrence.

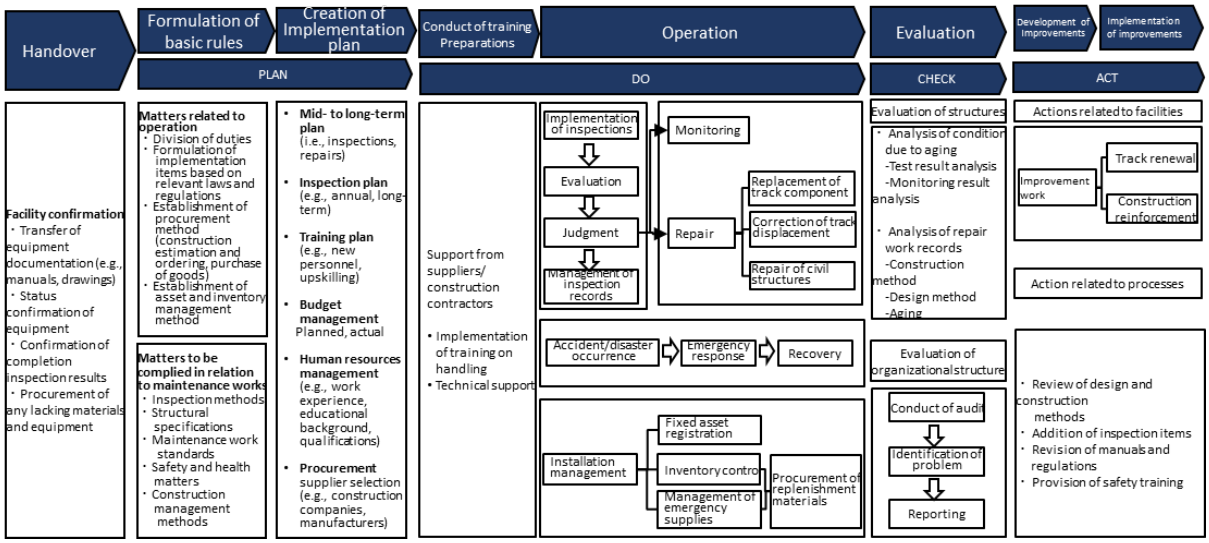


Figure 2-9 Overview of Tracks and Infrastructure Department Workflow

2.4.6 Rolling Stock Department (Handbook P45-P46)

(1) Basic Concept

Rolling stock maintenance can divided into two (2) broad categories: (1) preventive maintenance, wherein regular inspections are performed according to a schedule; and (2) corrective maintenance, wherein repairs are performed in the event of an accident or failure. To reliably implement these maintenance activities, the following should be formulated: mid- to long-term renewal plans for rolling stock; process plans for inspections; troubleshooting and emergency management plans; and implementation system.

Spare parts, special equipment, and their management are indispensable for maintenance. Furthermore, daily maintenance data are collected and analyzed to detect the early signs of failure, implement the necessary measures, and reflect these in the improvement plan.

Rolling stock personnel (e.g., engineers, technicians) must have the necessary knowledge and expertise to carry out their respective duties effectively. This can be achieved by conducting theoretical and practical training using easily understandable training materials.

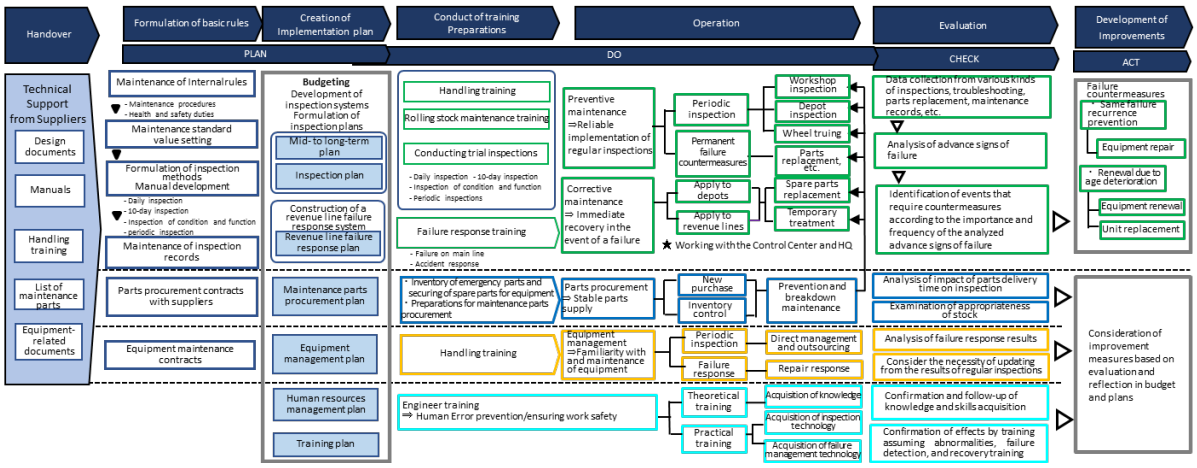
(2) Points for Consideration

The Figure 2-10 illustrates the series of activities, beginning with the receipt of the rolling stock and inspection equipment up to the deployment of improvements needed after the railway system opening.

Regarding Rolling stock inspection system, utilizing the inspection books prepared by suppliers, the following should be prepared: regulations and manuals; inspection plans; revenue line failure response plans; and pre-opening training and other activities in preparation for conducting actual inspections. The high quality of rolling stock inspections and troubleshooting activities must be maintained and continuously enhanced by continuously finding improvement points and making corrections even well beyond the railway system opening. And lists of parts with the necessary details (e.g., names, model numbers, quantities, and replacement cycles) are obtained from the suppliers. Based on the formulated inspection plan, a procurement plan for acquisition of the spare parts necessary for maintenance and contracts with corresponding suppliers should be formalized. The control of goods and appropriate stock of spare parts are maintained based on this plan.

Regarding Equipment maintenance system, pertinent equipment documentation is obtained from the manufacturer, and an equipment maintenance plan is developed in line with the inspection plan. Regular inspections are conducted to maintain the integrity of the equipment.

Regarding Skills training, a human resources management and training plans are formulated for the acquisition of knowledge and skills that are necessary for rolling stock maintenance. The training contents must be developed in accordance with the years of experience and level of skills of each trainee, as well as the necessary licenses for maintenance activities. For safety training, it is important to foster culture and awareness through constant repetition.



Source: Study Team

Figure 2-10 Overview of Rolling Stock Department Workflow

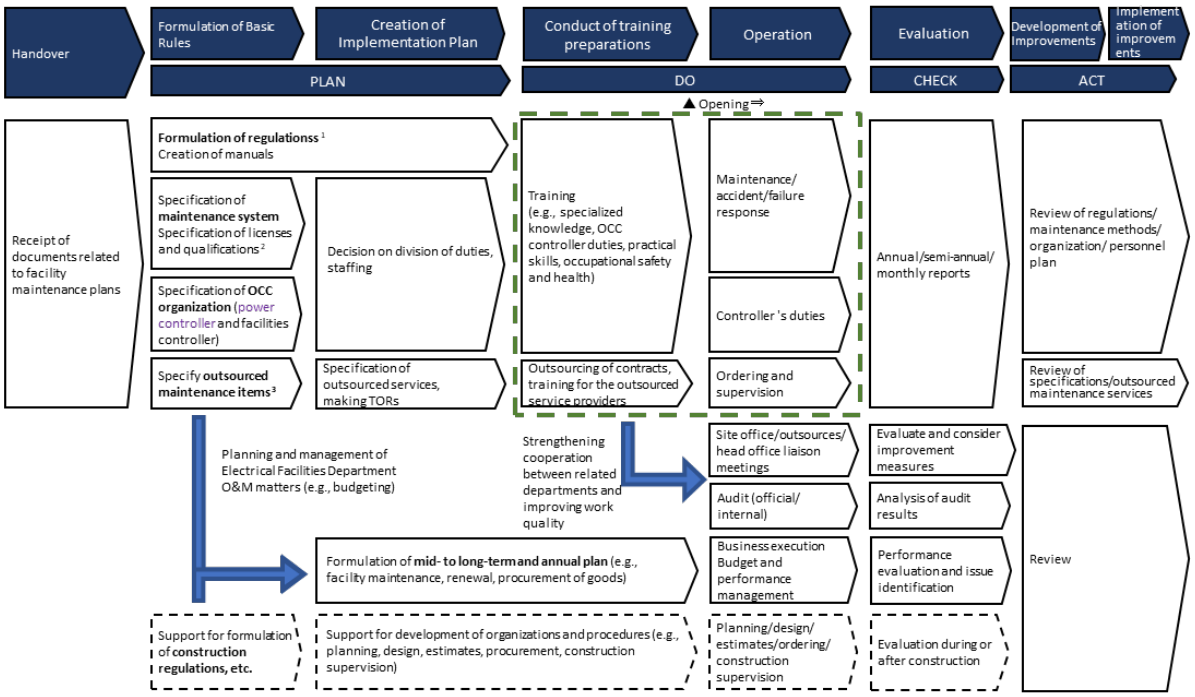
2.4.7 Electrical Facilities Department (Handbook P47-P48)

(1) Basic Concept

The Electrical Facilities Department covers a wide range of subsystems that are broadly divided into three (3) categories10: (1) power supply and transmission to the entire railway system; (2) signaling and communications that ensure safe train operations; and (3) station facilities that passengers can use comfortably and safely (e.g., electro-mechanical facilities and automatic fare collection).

(2) Points for Consideration

Figure 2-11 shows the basic workflow of the Electrical Facilities Department, which is common to all categories, before and after the opening of the railway system. The coverage workflow until railway pre-opening is further explained below.



- The three (3) categories are color-coded throughout the discussion

[1] Electrical Facilities Department alone): maintenance of electrical facilities, electrical power operations, radio (wireless) use; Cross-departmental: working on tracks, working on trains after operations, handling of maintenance vehicles

[2] Licenses/qualifications (e.g., chief electrical engineer, radio use, EWES, handling dangerous materials, ordinary driving license, occupational safety and health)

[3] O&M of extra high-voltage facilities and radio stations, maintenance of power supervisory control and data acquisition (SCADA), operation management devices and data transmission network devices, specification of cooperating companies to undertake construction works, and other tasks. For many station facilities (e.g., EWES, PSD, AFC), outsourcing needs to be considered, so it is particularly necessary to provide support for outsourcing contracts and assume that training for outsourced companies will be needed.

Figure 2-11 Overview of Electrical Facilities Department Workflow

1) Formulation of regulations

There are regulations specifically for the O&M of electrical facilities (e.g., electric power), as well as regulations that apply across different railway O&M fields (e.g., duties to be performed after the last train of the day, maintenance vehicle handling). Manuals define the procedures intended for maintenance works and applications, among others.

2) Maintenance system

It must cover the said three (3) categories and also include the necessary personnel and their designated duties.

3) OCC organization

The OCC typically has different controllers for train operation, station operation, rolling stock, and power. In line with these, the Electrical Facilities Department must establish organizations for the power controller; while establishing organizations for the facilities controller should be done in collaboration with the Infrastructure Department.

4) Outsourced maintenance items

Tapping outsourced technical expertise is typically in response to a need for highly specialized capabilities or cost reduction.

5) Post-opening

After opening, put duties into practice, assess, and shift to a routine of implementing improvement.

2.4.8 Department for Cross-Departmental Integration (Handbook P49-P50)

(1) Basic Concept

The previously mentioned departments for the train operations, station operations, infrastructure, rolling stock, and electrical facilities carry out their respective duties, which include the management of the assets under their jurisdiction. However, passengers see the railway system as a single entity that provides transport services and not as individual departments providing individual services. Therefore, it is ideal to have a special department that is responsible for cross-departmental cooperation by establishing goals and rules that integrate the different O&M departments.

Figure 2-12 shows Overview of Cross-Departmental Integration Department Workflow.

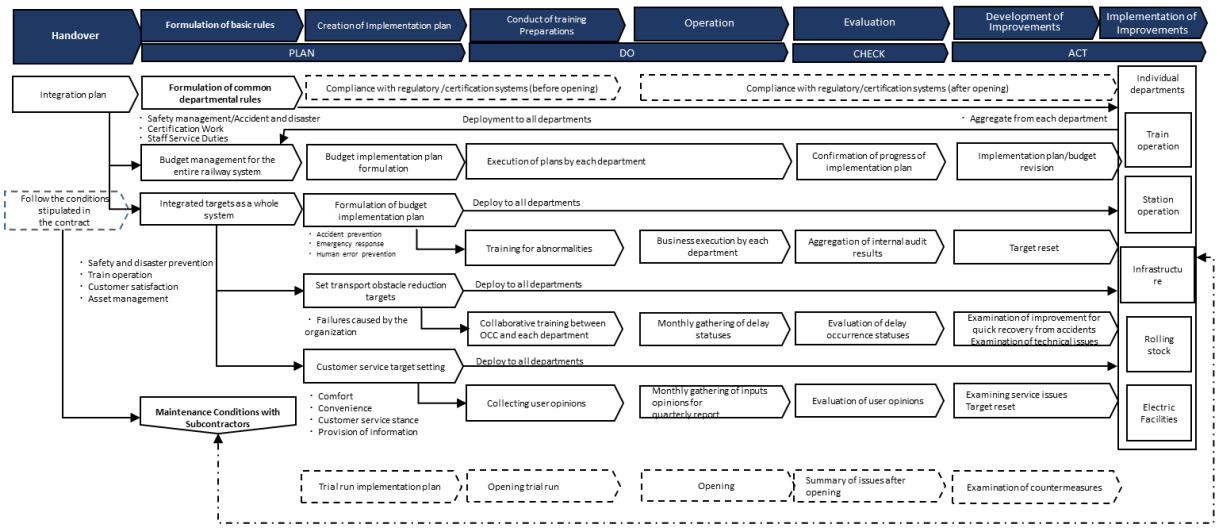


Figure 2-12 Overview of Cross-Departmental Integration Department Workflow

(2) Points for Consideration

Formulation of common departmental rules

Formulating and implementing unified rules that apply to all departments, such as safety management and emergency management, is essential to achieving integration. Basing department regulations on these common rules can help in monitoring and traceability.

Budget management and inter-departmental coordination

Budgets required for each department are aggregated so the Budgets required for each department are aggregated to determine the overall budget for the entire organization. This integration is expected to optimize overall management of the organization and railway system.

Cross-departmental integration targets

Safety targets are set for accident/disaster prevention, train operation stability, customer service improvement, and asset management quality. In this management process, activities to solve technical and service issues across departments are also conducted. It is necessary for all of the said activities to be carried out using the PDCA cycle in the same way as other departments.

Coordination of maintenance conditions and other related aspects

When outsourcing maintenance services, contract terms are negotiated. In case of newly opened railway lines, plans for overall trial runs are created.

2.4.9 Asset Management (Handbook P51-P54)

(1) Basic Concept

In order to effectively utilize railway assets owned by governments and other implementing entities during their useful life and maintain the financial stability of operating entities, it is necessary to support the preparation and implementation of asset management by the said entities through JICA projects. This section describes the related basic concept and points to be considered during the preparatory stages (until the GC stage) and the operational stage. Asset generally refers to the properties necessary for railway operations, such as stations, tracks, signaling system, and rolling stock. Asset management pertains to the maintenance of the condition of assets at a specified level, consisting of a series of work cycles, such as planning, implementation, evaluation, and improvement.

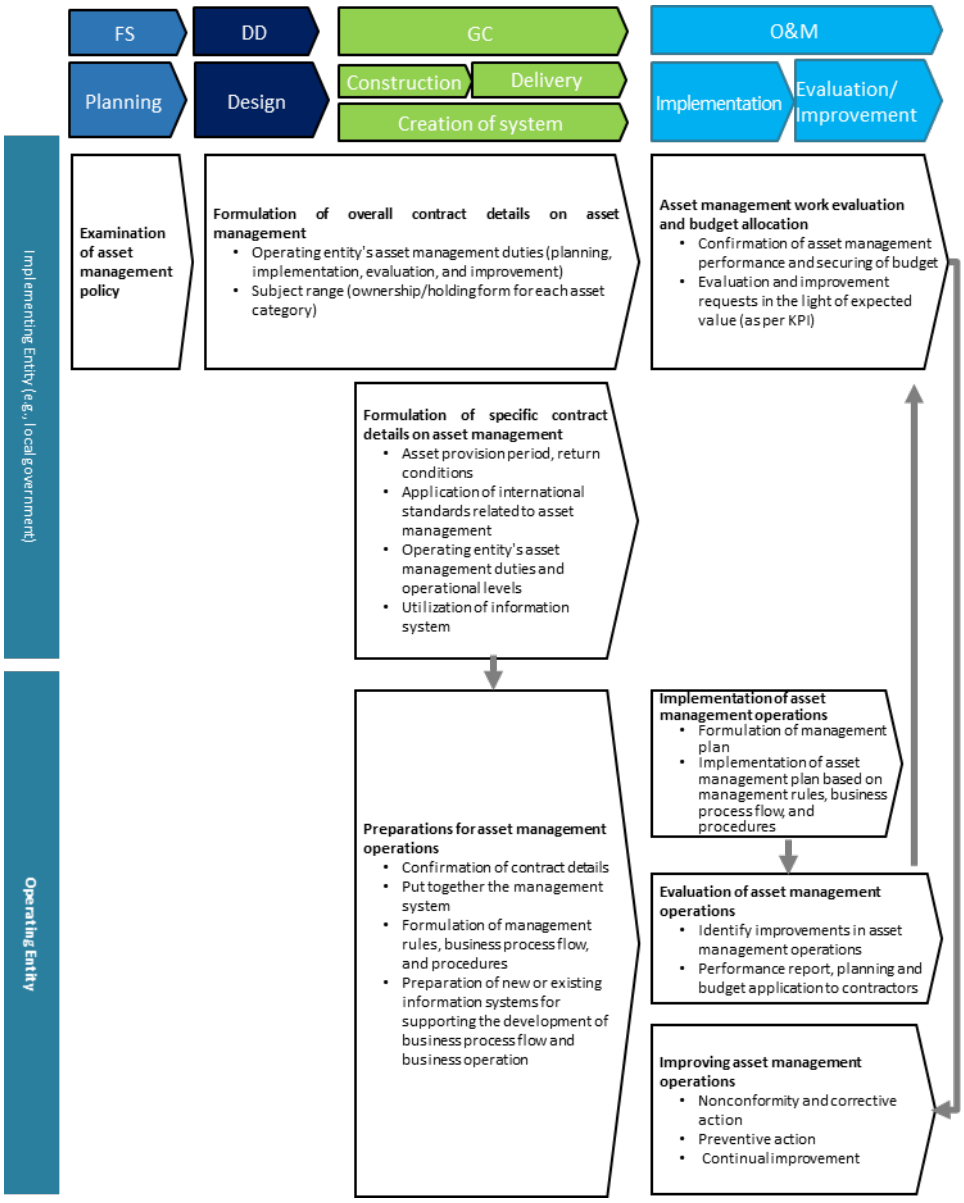


Figure 2-13 Overview of Asset Management Preparations and Operations

(2) Points for Consideration

1) Examination of asset management policy

The process of examining the asset management policy by the implementing entity is supported

through JICA projects by presenting references on asset management work and examples. ISO 55000 (ISO55k), the international standard for asset management system, may be applied, as it is used in the railway industry. On the other hand, the Asset Management Working Group of the International Union of Railways has deemed Japan as the most certified country in 2019, so Japanese cases can be considered an international standard worth considering[1].

2) Formulation of overall contract details

The implementing entity considers the scope of jurisdiction (e.g., scope of assets, form of ownership, business operation) of the operating entity in terms of asset management; and JICA projects support this process by providing relevant case studies from Japan and other countries.

3) Formulation of specific contract details

The implementing entity details contract for asset management; and JICA projects support this process by providing relevant case studies from Japan and other countries. The use of information systems can be considered in areas with concerns of staff turnover, as it is possible for business process flows to be created and a certain business operation level can be secured without depending on personnel. The said systems can be expected to keep the evidence for securing the budget with transparency and objectivity by designing appropriate information management in relation to asset management plans and achievements between operating and implementing entities.

4) Preparations for asset management operation

The implementing entity confirms if the preparation status of the asset management work conducted by the operating entity aligns with the contract details previously agreed upon. JICA projects provide relevant assistance in business process flow and procedures, as well as preparations or procurement activities needed for information system utilization.

5) Implementation, evaluation, and improvement of asset management operations

The implementing entity confirms if the operation cycle for asset management is appropriately established by the operating entity. JICA projects support this particular action by providing relevant confirmation points for the implementing entity. By using the assessment viewpoint of ISO55k, a set of confirmation

6) Asset management work evaluation and budget allocation

The implementing entity regularly receives performance reports from the operating entity based on a pre-established asset management business plan. In addition to the ISO55k assessment, JICA projects can also consider supporting other asset management activities based on the KPIs of the implementing entity.

(3) Examples of Asset Management in Different Countries

The following are examples from Australia and the United Kingdom (UK), where ISO55k is the de facto standard in the railway industry[2]. In addition, the utilization status of the information systems,

[1] While this page describes management works related to tangible assets of railway, ISO55k is a standard for asset management that includes both tangible and intangible assets (e.g., intellectual property rights).

[2] This standard is used in Australia and several other parts of the world in the other fields (e.g., electric power utilities, water treatment and sewage systems) as well.

which is an important matter in the said standard[3], is explored in this section.

1) Australia

A government-affiliated company owns the land, infrastructure, E&M system, and rolling stock of the Metropolitan Rail Service in Melbourne. In accordance with the O&M contract with the state government implementing entity, an O&M entity conducts their business using these assets for a certain period of time.

The O&M entity, Metro Trains Melbourne Pty. Ltd. (MTM), has leased these assets from the implementing entity from 2017 to 2024 and are contractually required to return the assets in a usable condition by the end of the contract period. For this reason, the O&M entity formulated an asset management plan and is conducting asset renewal and maintenance work pursuant to the said plan.

The implementing entity contractually required the O&M entity to obtain an ISO55k certification, which the MTM has acquired. The MTM previously obtained a PAS55 certification, which is a British Standard, the basis of ISO55k certification, and eventually transition to a ISO55k certification within the contract period. In line with this, the MTM has systematized its management regulations and business processes as a part of its asset management system framework. In accordance with ISO55k standards, the MTM performs a series of operations from planning to internal audit, as well as conducts regular performance evaluation of its asset management operations in management reviews; nonconformity items are improved, which are then reflected in succeeding plans.

The MTM has implemented a packaged information system built around the ISO55k standard that manages pertinent information on assets leased from the implementing entity. Some of the information being managed include: registration and condition of assets and maintenance activities; acquisition price and book value of replacement and spare parts; and inventory statuses and utilization schedules of spare parts. Since the MTM and implementing entity are mutually connected to each other's asset management information systems, the said information can be immediately obtained from the implementing entity. In addition, since the data are also used for performance and accounting reports in the asset management plan, accurate information can be immediately obtained, thus enabling timely budget preparation and approval.

2) United Kingdom

First MTR South Western Trains Ltd. manages the assets mainly for the stations and related facilities of the South Western Railway as an O&M operating entity[4]. Similar to the case of the MTM in Australia, ISO55k certification is a requirement, and an ISO55k-based packaged information system is utilized.

[3] In ISO55k, information systems are positioned as enabling mechanisms and considered one of the most important items to address. As for the case of other railway systems overseas, adapting packaged information systems based on the ISO55k has become the conventional approach.

[4] The asset management system is expected to be further reviewed by the "Great British Railways" plan announced by the British Ministry of Transport in May 2021.

3) Summary of Asset Management Examples

Table 2-2 Examples of Asset Management in Different Countries

			Australia	UK
O&M operating entity (Abbreviation: Lead investor)			Metro Trains Melbourne Pty. Ltd. (MTM: Hong Kong MTR 60%)	First MTR South Western Trains Ltd. (FMSWT: UK First Group 70%)
Implementing body concluding contract with O&M operator			Public Transport Victoria	Department for Transport
Name of railway line			Melbourne's metropolitan rail service	South Western Railway
	Asset owner	Land	Government-affiliated company	Government-affiliated company
		Infrastructure	Government-affiliated company	Government-affiliated company
		E&M system	Government-affiliated company	Government-affiliated company
		Rolling stock	Government-affiliated company	Private sector enterprise (rolling stock leasing company)
		Stations	Government-affiliated company	Government-affiliated company (partly O&M operators)
Overview of asset management contract	Contract period		・ 2017 until 2024	・ 2017 until 2024
	Assets to be managed by the O&M operator		・ Assets owned by government-affiliated companies	・ Assets owned or leased by O&M operator (stations and station equipment)
	Special note		・ Under the terms of the lease agreement, ownership is transferred to the O&M operating entity. Upon termination of the contract, the assets are to be returned in a condition in which they may continue to be used.	・ Collaboration in maintenance management work for assets owned by government-affiliated companies and private sector enterprises
O&M operator's asset management work	Main work contents		・ Formulation of asset management plans ・ Implementation and recording of asset renewal and maintenance work	・ Formulation of asset management plans ・ Implementation and recording of equipment renewal and maintenance work
	Tasks related to budgeting for asset maintenance and renewal		・ Mid to long-term asset management planning in line with business KPIs ・ Detailed annual work plan based on asset management plan (including financial plans such as for material procurement and maintenance costs)	・ Annual business plan for stations and station asset (including financial plans for material procurement, maintenance costs, etc.)

		Australia	**UK**
	Compliance with international asset management standards	Certification required	Certification required
Asset management information systems	Systems currently in use	ABB Ability Ellipse EAM	Infor Asset Management System
	Systems currently in use	・ Management of asset information and work information ・ Information sharing with asset owners	・ Management of asset information and work information

2.5 O&M Case Studies: Implementation System and Business Development Strategy

2.5.1 Overseas O&M Projects (Handbook P55-P56)

Table 2-3 is based on public information concerning the O&M operations carried out by national railway operators in other countries: Arriva in Europe, FirstGroup in the U.K., Hong Kong-based MTR in Melbourne, Australia, and France-based Keolis in Dubai.

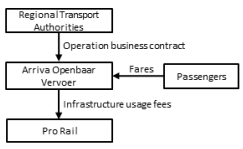
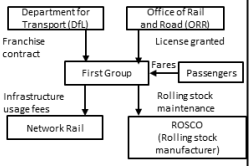
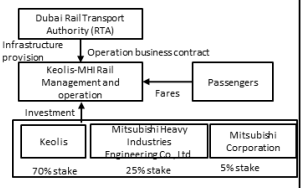
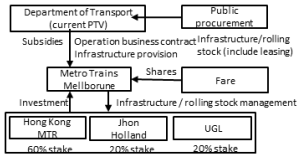
(1) O&M Implementation System per Organization

As shown in the Table 2-3 highlighting related O&M case studies, even in cases where maintenance of the railway facilities and rolling stock are originally segregated, a business scheme can have actual O&M functions divided several JV member companies instead of being performed by a singular company.

(2) O&M Business Development Strategy

It appears that the trend for developing O&M businesses is that these are mainly structured without large asset holdings, but are more based on the acquisition of local knowledge and the continuous capacity advancement of personnel responsible for the O&M operations. Under this this kind of business model, while the profit margin is considered low (around 2-3%), the risk margin is likewise considerably small. Such model also features a more stable cash flow — one of the important considerations for O&M businesses.

Table 2-3 Overview of O&M Case Studies

Name of Operating Entity (Country of Origin)	**Arriva** (UK)	**First Group** (UK)	**Keolis** (France)	**Hong Kong MTR** (Hong Kong)
O&M Implementation Cities	Netherlands	UK cities	Dubai	Melbourne
Legal System	European certification system	European certification system	European certification system	TSV (Transport Safety Victoria) carries out safety supervision work, in accordance with the Rail Safety (Local Operations) Act 2006 (Vic).
O&M Implementation System	Arriva formed a JV with a local small railway operator (Openbaar) and is responsible for train operation and rolling stock procurement. Infrastructure maintenance is handled by Prorail.	Only the train operation business is conducted, and infrastructure maintenance is handled by Network Rail, and rolling stock procurement and maintenance are handled by ROSCO (a vehicle leasing company) and the rolling stock manufacturers.	Carries out Dubai O&M business in a JV with a Japanese company. Keolis is in charge of the train operation business, and maintenance is handled by MHI.	Melbourne O&M work carried out in collaboration with local companies John Holland and UGL. Equipment maintenance is handled by John Holland and UGL.
Business Scheme				
Business Scheme Framework	Public investment/gross cost	Public investment/gross cost	Public investment x gross cost	Public investment x gross cost
The general trends of each company are described below.			The general trends of each company are described below.	
Risk Management	The company has offices all over Europe involved in the operation of large coaches. The company has is extremely knowledgeable about the regulatory requirements of each country and have systems in place that can respond to concerns promptly.	Management is conducted based on franchise contracts.[17]	Considering the acquisition or future acquisition of an existing local railway operator, the company initially plans to form a partnership[19] to avoid escalation of its own risk.	The Melbourne O&M business uses a risk sharing method with the ordering party. The operator takes the risk related to the upper and lower limits of the agreed upon fare income plan. Burdens in excess of these limits is split between the state government and the operator.
O&M Business Development Strategy	They conduct their bus operation business first, and acquire knowledge about target destinations. As a JV participant in the railway business, the company further grows their business by acquiring local companies.	Currently working to maximize profits within franchise agreements.[18]	In addition to the home base, France, the company aggressively pursues business opportunities in other European countries and in the US, Middle East, and Asia. They implement extensive training in-house. Through this transfer of knowledge to their employees, they are conducting O&M operations in various regions across 14 countries.	The focus is on projects where they can operate and maintain existing routes with relatively small investments, even if the profit margin is not high.

2.5.2 European Authorization and Certification System (Handbook P57-P58)

(1) European System

Distinct from the Japanese practice, the third-party certification body under this system involved in the authorization and certification proceedings follows the European custom. Risk-based explanations and certification body reviews are fundamental for this style. Such system is highly applicable for instances wherein authorization and certification systems are within the purview of regulatory entities that cannot secure evaluation skills and resources. The practice of this system is found in various countries and regions, such as Southeast Asia. The flow of the European-style of authorization and certification is shown in the Figure 2-14. From the perspective of a donor country, if there is already an existing railway project funded by another country, it is necessary to pay attention to the trend of the licensing system in the recipient country concerned.

(2) Safety requirements

There may be cases wherein the recipient country's laws stipulate requirements for railway O&M or safety evaluation is stipulated in project implementation. As to safety and performance requirements for railway systems, there are cases wherein conformity to standards related to Reliability, Availability, Maintainability, and Safety (RAMS; e.g., IEC62278), submission of documents, and assessment by a certification body are also required. As for O&M requirements for railway systems, the establishment of an operational safety management system is required in Europe, which has been similarly adopted in Vietnam. There is also a possibility that this trend will spread among emerging economies in the future.

(3) RAMS requirements

The requirements for operation safety management system is directly carried out by the operating entity; while contractors are required to meet the safety and performance requirements of railway systems based on the risk assessment, as stipulated in RAMS-related standards. Contractors submit a document called safety case after being assessed by a certification body, as necessary.

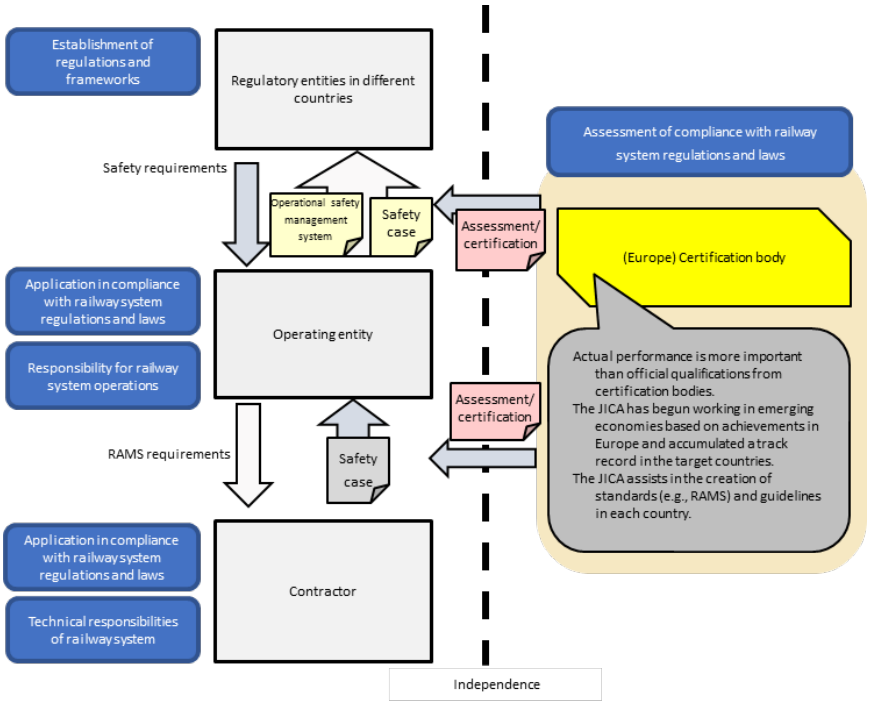


Figure 2-14 Flow of European-Style Licensing in Emerging Economies

2.5.3 Key Performance Indicators (Handbook P59-P60)

(1) Kinds and Rolls of KPI

There is a wide range of KPIs related to O&M, as seen in the Figure 2-15, which include those related to operations (e.g., safety, punctuality), customer satisfaction, assets (e.g., rolling stock, station facilities), personnel, and social impact (e.g., environment, corporate social responsibility).

There are some cases wherein KPIs are stipulated in the O&M contract; while in other cases, these are set by the operating entity. The role of KPIs is to serve as a baseline for service levels and O&M performance, as well as a criteria for awarding bonuses or penalties based on the attainment of this baseline if stipulated in the contract. If set by the operating entity independently, KPIs can also help with the improvement of O&M performance and management.

(2) Sample Application

An example of KPI application overseas is Hong Kong MTR's use of KPIs as a tool and evidence of social contributions (e.g., inclusion of KPIs in sustainability reports) to countries in which it invests. Aside from business use, KPIs are also utilized for index fare adjustments.

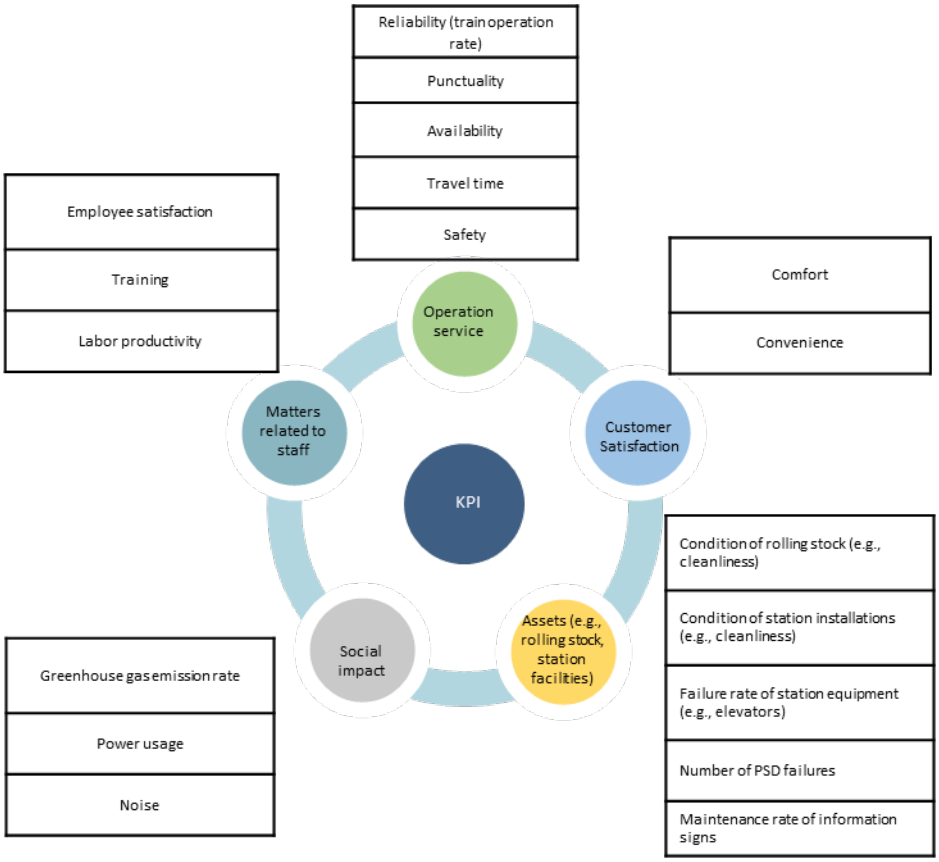


Figure 2-15 Examples of O&M-related KPIs

2.5.4 O&M Business in Japan: Comparison of Subway Businesses (Handbook P61-P62)

(1) Basic Information

Interview surveys were conducted with the following six Japanese businesses.

Table 2-4 Comparison of Japanese Subway Businesses

Source：Comparison of Japanese Subway Businesses (MLIT, 2018)

Item /Operator	Fukuoka City Transportation Bureau	Kyoto Municipal Transportation Bureau	Tsukuba EX	Transportation Bureau City of Nagoya	Bureau of Transportation. Tokyo Metropolitan Government	Tokyo Metro
Management type	Public management	Public management	Third sector	Public management	Public management	Co., Ltd.
Operation type	Vertically integrated	Vertically integrated	Vertically integrated	Vertically integrated	Vertically integrated	Vertically integrated
Line length (km)	29.8	31.2	58.3	93.3	109.0	195.1
Passengers carried/day (1,000 people/day)	470	397	386	1,336	2,821	7,579
Passenger kilometer[20] (1,000km/day)	2,464	2,077	7,662	8,433	20,319	60,787
Number of personnel	576	638	698	2,745	3,486	9,666
Fare range (JPY)	210-380	220-360	170-1,210	210-340	180-330	170-310
Railway operating revenue (million JPY)	30,945	28,256	46,340	83,725	152,996	383,372
Railway operating expenditures[21] (million JPY)	26,269	25,446	38,307	70,237	125,980	301,314
Operating expenditures[22] (million JPY)	13,336	12,212	14,454	43,713	79,824	193,853
Ordinary income[23] (million JPY)	4,676	2,810	8,033	13,488	27,016	82,058

Note: Passenger kilometers is passengers carried multiplied by average distance traveled. Railway operating expenditures is all expenditures for the purpose of operations as a railway operator. Meanwhile, operating expenditures (transportation expenses) is the total of personnel expenses and direct operating expenses for conducting, stations, tracks, electricity, and rolling stock (excluding general administrative expenses) as required for O&M, and does not include depreciation and amortization, taxes, benefits, non-O&M expenses, etc. Ordinary income is railway operating expenses minus railway operating revenue. (Source: Railway Business Accounting Rules)

(2) Organizational Structure

1) Organizational Structure, Personnel Structure, and Operational Implementation Structure

Although each department within an organizational structure has different department names and divides duties differently, there are not huge differences between the department responsibilities and the roles themselves. Figure 2-16 provides an example head office organization.

Regarding the personnel structure, its size is roughly equivalent to operating kilometers. However, each business entity may account for a different share in each department depending on how much work is contracted out.

As for the operational implementation structure, operations requiring the expertise or special qualifications unique to the railway operator are carried out directly by said operator. Meanwhile, when it comes to other operations, or when an outside company possessing expertise has been contracted, outsourcing will work toward streamlining personnel assignments. An outside company possessing expertise could be one that, for example, produces equipment or systems the railway operator has installed.

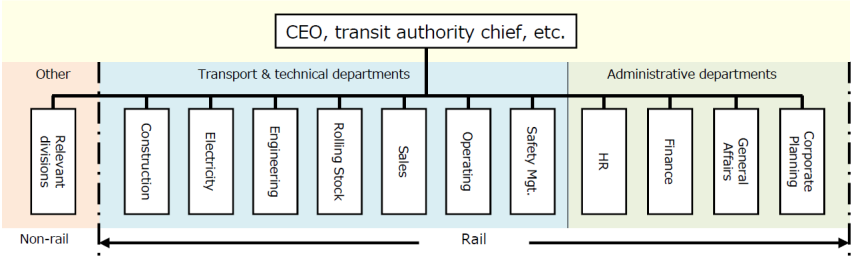


Figure 2-16 Example of Typical Head Office Organization

2) Hiring Employees

Expert roles assigned to the head office are mostly filled by a business entity that reassigns experienced personnel to each department. Therefore, when a fresh graduate is hired directly, it tends to be limited to a career track for university graduates who may join the company's management team in the future.

Regarding employees engaged in on-site work, all businesses responded that their transportation department initially hires them as station attendants, and that they can join train crews or transferred to other positions upon passing a promotion test. Meanwhile, each technical department hires its employees into technical positions. In addition, all businesses stipulate required academic backgrounds in certain fields of study according to the knowledge needed for the work.

3) Post-hiring Training

After hiring employees, each business carries out training, such as new employee training, training to transfer to a new position or obtain certifications, and post-hiring follow-up training. The training provides employees with the knowledge and technical skills required for safe and reliable O&M.

(3) Profitability/Revenue Fluctuation Risk Management

1) Profitability

As far as can be seen among the surveyed businesses, the 15-20% level seems to be a reference figure for continuing steady railway operations. Although there is a general correlation between transport density and profitability, this shows that transport density is an indicator of high transport efficiency (i.e., a factor for generating high profits).

2) Revenue Fluctuation Risk Management

In the planning stage, it is difficult to determine what to consider and how deeply. In addition to the recent global pandemic, foreseeable political conditions and economic change in a given country are among the factors that influence how many passengers railways carry. These matters should be considered while taking into account resources such as expert opinions.

3) Operating Expenditures (Fixed Expenditures)

Operating expenditures are a railway's direct O&M costs. No matter the size of the business, the amount per employee is in the area of 20 million yen per person. This backs up the notion that the number of personnel and as a result the size of the organizational structure, is proportional to the amount of work required for O&M.

A point to keep in mind here is that even if there is a large decrease in operating revenue, whatever the reason, operating expenditures for labor and maintenance of the equipment required for train operations do not fluctuate very much.

(4) Business Strategy (Rider Services, etc.)

An overarching trend is that every company makes efforts to address the five following items: safety measures, high-quality transportation services, stronger business foundation, environmental action, and contributions to community development.

(5) Asset Management

While at some companies all departments are involved in the introduction of asset management systems and operating conditions, only some departments are involved in others, but there is asset management in some form at every company.

2.5.5 Mumbai Metro Line 1, India (Handbook P69-P70)

For Mumbai Metro Line 1, the private sector has taken care of O&M, including the initial investment, and owns the assets. The line faced financial difficulties upon opening. It is a case indicating the difficulties of a privately managed company bearing the burden of initial investments, even for a line expected to have robust demand.

(1) O&M Operational Scope, Role, Business Scheme, Revenue Method, Profitability, KPI, etc.

1) Business Scheme

Mumbai Metro One Private Limited (MMOPL) concluded a 35-year concession agreement that includes a five-year construction period. MMOPL owns the Mumbai Metro Line 1 elevated structures, stations, pedestrian bridges, rolling stock depots, rolling stock, signaling equipment, electrical equipment (including SCADA), communications equipment, tracks, fare reception system, and so on. MMOPL outsourced to Veolia Transport India 10 years of transit services from the time of opening, as well as the hiring and training of up to 550 personnel until the line's opening.

2) Business Conditions

MMOPL faced financial difficulties when it posted an annual loss of 3 billion rupees (5 billion yen) in 2016. Although fare revenue can cover operating expenditures, interest payments and other financial costs put pressure on the business. Before the line's opening, MMOPL requested a fare hike to the state government, but the state government settled on a lower price. Despite O&M laws stipulating the establishment of a fare-setting committee, the state government intervened to take extrajudicial measures. This action caused future problems, and MMOPL went to the High Court of Bombay in 2014 to request the appointment of an arbitrator.

3) KPIs

MMOPL sets its own KPIs for risk management and raising enterprise value. Service availability is 100% and punctuality is 99%. Transportation performance provides other indicators such as number of trips, rolling stock kilometers, and annual ridership. Other indicators include train interior cleanliness and number of complaints, which shows there is an emphasis on customer service. There are also RAMS-based indicators, which gives the impression that European standards have been widely adopted.

4) Organizational Chart and Number of Personnel

Veolia Transport India's transit services were later taken over by Transdev and the Paris subway (RATP), which acquired Veolia. Under a five-year agreement affecting personnel hiring and training following the line's opening, 825 personnel had completed training as of 2017. Those personnel had logged a total of 29,060 hours of training, which includes a variety of content, such as more than 50 training modules.

(2) Lessons for JICA Projects

1) Commercial Perspective

- A BOT scheme including the initial investment creates enormous risk for a private company.
- A delayed opening could push back revenue opportunities for a private company
- Government intervention in setting fares requires government compensation if the fares are set low.

2) Technical Perspective

- Personnel hiring and training are outsourced to an Indian company that is an international operator

(for the first time for the project).

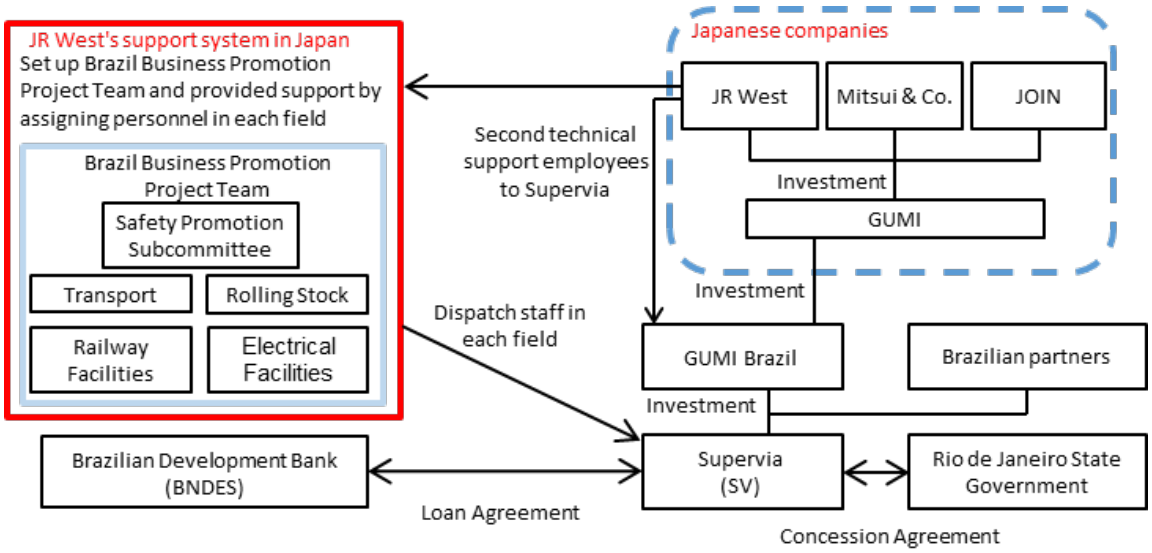
- KPIs following European standards have been widely adopted (including RAMS-based indicators).
- The same operator company arranges training and technical transfers via a company from a third country, which strengthens operations and maintenance capabilities.

2.5.6 Rio de Janeiro State Suburban Railways, Brazil (Handbook P71-P72)

(1) Business Scheme

The joint venture company, Guarana Urban Mobility (GUMI), consists of JR West, Mitsui & Co., Ltd., and Japan Overseas Infrastructure Investment Corporation for Transport & Urban Development (JOIN) participates in Brazilian passenger railway business by indirectly holding shares in Supervia, Rio de Janeiro State Suburban Railways. (Figure 2-17shows the scheme of the project.)

Supervia has been granted the railway operating rights since 1998 through a concession contract from the State of Rio de Janeiro. It has 8 lines30 and 104 stations with a total route length of 270 kms. With more than 2,000 employees, the average daily number of passengers in 2019 was 590,000, which is comparable to a major Japanese railway.



Source: Compiled by the study team based on interviews with JR West

Figure 2-17 Rio de Janeiro State Suburban Railways Business Scheme Diagram

(2) Lessons for JICA Projects

- Business participation and technical support was provided through indirect investments in the existing urban railway lines in a developing country
- Technical support was provided through advisories while respecting local ideas, customs, and speed.
- Local support was provided by setting up the project team and sending Japanese resident officers.

2.5.7 MRT Jakarta North-South Line, Indonesia (Handbook P75-P76)

(1) Business Scheme

The implementing entity, MRTJ, operates and maintains the railway as the operator. Government funding is drawn from a JICA ODA loan. Figure 2-18 shows the business scheme diagram.

Japanese companies, such as the Shimizu Corporation and Sumitomo Mitsui Construction, undertook the construction of infrastructure installations. Nippon Sharyo provided the rolling stock, while Mitsui & Co., and Toyo Engineering were responsible for the E&M systems.

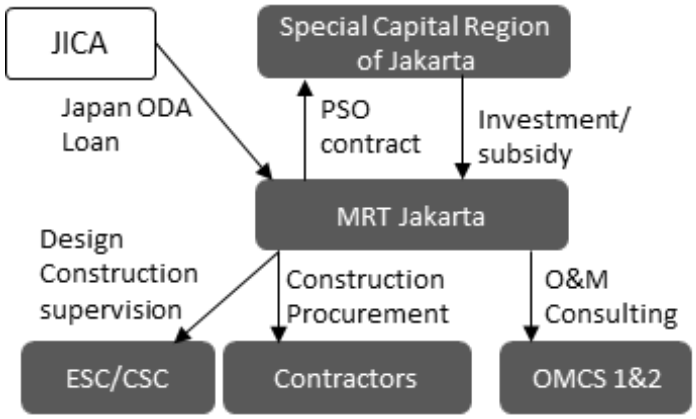
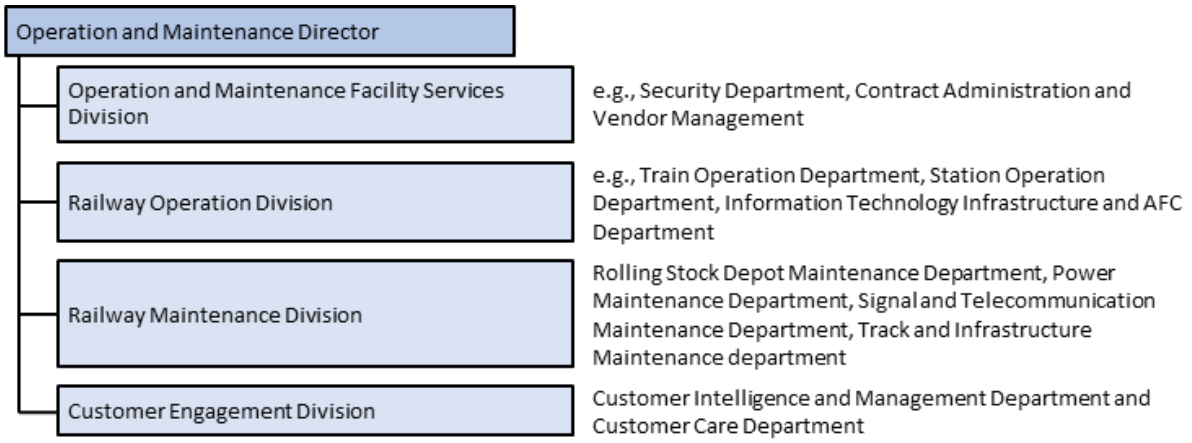


Figure 2-18 MRTJ's Business Scheme diagram

(2) Organization

The O&M headquarters is set up, with several departments (e.g., Operations and Maintenance) placed there. Figure 2-19 shows MRTJ O&M headquarters.



Source: compiled by the study team based on MRT Jakarta Annual-Report 2019 [5]

Figure 2-19 MRTJ O&M headquarters (MRTJ, 2019)

(3) Key Points for JICA Projects

- This involved government investment and direct management of MRT Jakarta (MRTJ) as the

[5] https://jakartamrt.co.id/sites/default/files/2020-09/Annual-Report-MRT-Jakarta-2019.pdf

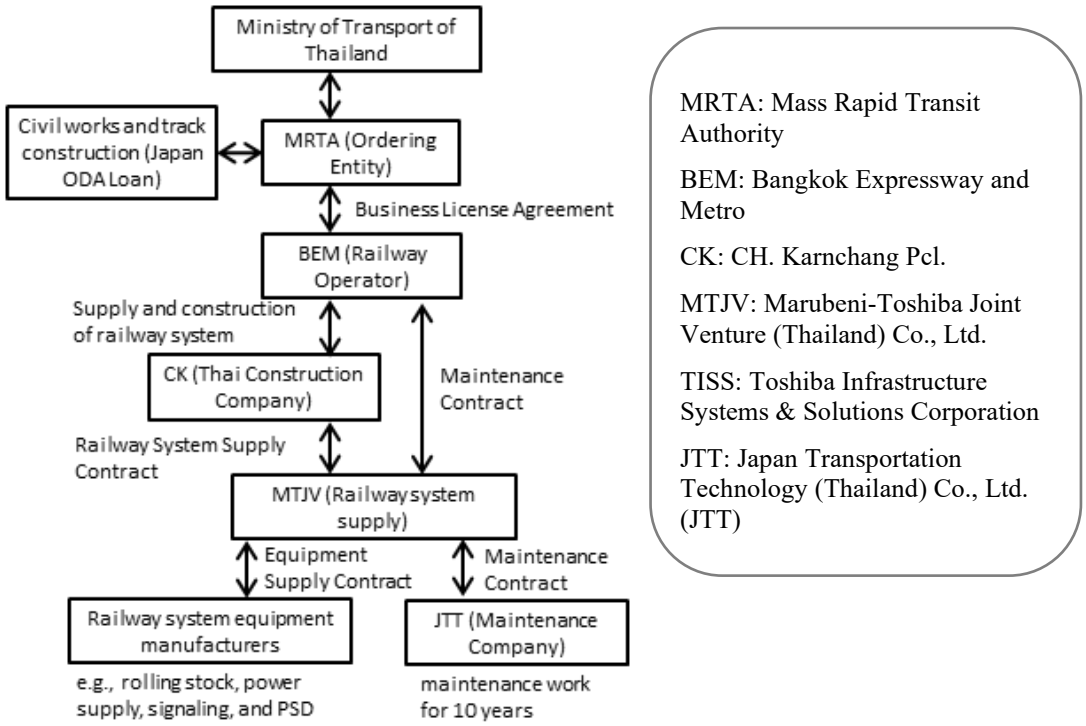
railway operating entity conducting O&M of the North-South Line, which is considered a future "cash cow line."

- Immediately after opening, the majority of income relies on state subsidies, which requires the government's financial capacity.
- The initial opening of the railway is considered a crucial time for railway operators. Balancing the revenue and expenditure by establishing demand at an early stage is urgently needed.
- Japanese railway technology and expertise are utilized for O&M and organizational structuring.
- Assistance continued even after the opening. This greatly contributed to the establishment and improvement of daily personnel duties.
- The organization along with the number of personnel are planned and implemented based on Japanese practice, making the system operate smoothly.

2.5.8 Bangkok Purple Line, Thailand (Handbook P73-P74)

(1) Business scheme (Figure 2-20)

- The MRTA which is under the Ministry of Transport of Thailand, is the main ordering entity in the construction and operations of the Purple Line.
- The BEM is given the railway operating rights and entrusted with the construction of the railway system under a business license agreement with the MRTA.
- The BEM subcontracts supply and construction of the railway system to CK.
- The MTJV is subcontracted to supply the railway system by CK.
- The JTT which is a consortium of Marubeni, TISS, and JR East, is entrusted with maintenance works for 10 years by BEM through MTJV. KPIs are also set for operational delays.
- Civil works and track construction were financed through a Japan ODA Loan.



Source: Compiled by the study team based on JREA 2019 Vol. 62 № 9 "Maintenance Operations on the Bangkok Purple Line," page 43456

Figure 2-20 Bangkok Purple Line Business Scheme Diagram

(2) Overseas railway O&M business reference points

- A case where a corporate alliance involves the participation of a Japanese railway operator for the maintenance of a local urban railway.
- Approximately a year after opening, the Blue Line was extended and connected, resulting in passenger ridership increases.
- Each design document requires approval not only from the CK but also from the BEM and MRTA. This greatly affected schedule management.

2.5.9 West Midland Trains, United Kingdom (Handbook P67-P68)

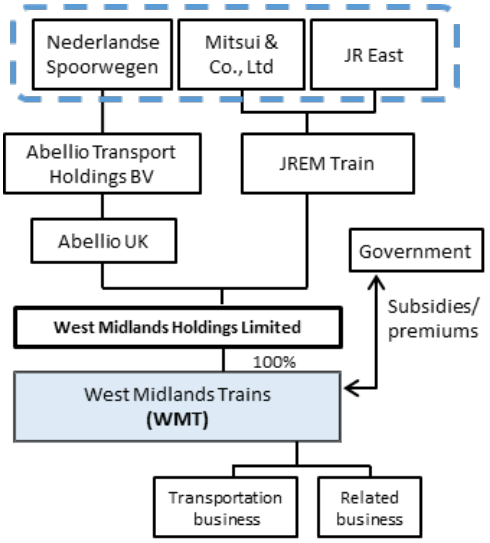
(1) Business Scheme (Figure 2-21)

The separation of railway infrastructure and operations is adopted in British railway businesses. The operating rights of each train operating company are determined through bidding.

In November 2016, JR East and Mitsui jointly bid with Abellio UK, a wholly owned subsidiary of Nederlandse Spoorwegen, and won the franchise for the West Midlands Trains (WMT).

Railway operations started in December 2017. The operating rights were taken over from Govia, a major British and French transportation company that was in charge of operations for 10 years. The operating entity is responsible for metropolitan transportation near London and Birmingham, as well as long-distance routes connecting London and Liverpool.

The franchise also includes the management of the Birmingham Snowhill Station, among others. The WMT, in which the three (3) said companies invested, is responsible for the actual operation work, with Abellio UK investing 70.1% while JR East and Mitsui have 14.95%, investment stakes, respectively.



Source: Compiled by the study team based on JR East and Mitsui press release dated on August 10, 2017 " Acquisition of Operating Rights for Passenger Rail Business in the United Kingdom"

Figure 2-21 WMT Business Scheme Diagram

(2) Overseas railway O&M business reference points

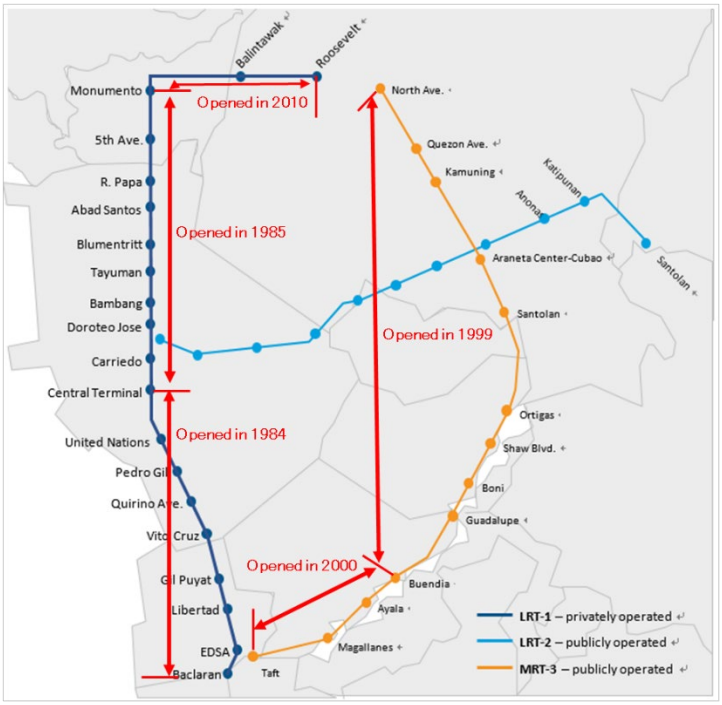
- This is a case where a Japanese company participated in a European railway business together with an overseas operator.
- JR East invested in a train operating company that operates the business, and it participates in management through a director it appointed.
- Punctuality is a specialty of Japanese railway operators and serves as a sales tool in obtaining operating rights.
- Personnel are deployed in the train operating company to provide knowledge on safety and operations while supporting the analysis and improvement in the transportation field.
- Personnel can continue their tasks even with a change of the operating entity. While the existing personnel can be utilized, they cannot be reconstituted in a short period.

2.5.10 Manila LRT Line 1 and Manila MRT Line 3, Philippines (Handbook P77-P78)

We investigated the two cases shown in Table 2-5 regarding railway O&M projects conducted by Japanese companies in other countries without the involvement of Japanese railway O&M operators.

Table 2-5 Cases to be surveyed

Line	Manila LRT Line 1	Manila MRT Line 3
Related Japanese Company	Sumitomo Corporation	Sumitomo Corporation Mitsubishi Heavy Industries, Ltd.
Involvement Activities	Investment in Railway O&M Company in Philippines	Receive maintenance order from Department of Transportation, Philippines
JICA Support	○（Past）	○（Current）
Operation（Station and Train Operation）	Railway O&M Company in Philippines	Under the direct control of the national government
Maintenance（Track, Bridge, Tunnel）	Railway O&M Company in Philippines	Receive rehabilitation order (Track)
Maintenance（Electrical Facilities）	Railway O&M Company in Philippines	Receive rehabilitation order
Maintenance（Rolling Stock）	Railway O&M Company in Philippines	Receive rehabilitation order



Source: Press Release of Sumitomo Corp. (May 29, 2020)[6]

Figure 2-22 Urban Railway Map in Manila

[6] https://www.sumitomocorp.com/ja/jp/news/release/2020/group/13410

(1) Manila LRT Line 1, Philippines

1) Outline

Manila LRT Line1 opened in 1984 with 19 stations and 19.6 km (as of March 2022), with an average daily ridership of approximately 460,000 passengers (in 2020) and fare revenue of 22,937 million Philippine pesos (in 2020, approximately 45,874 million yen *calculated at 1 Philippine peso = 2 yen). The assets are owned by LRTA, O&M is contracted to Light Rail Manila Corporation (LRMC) of the Philippines, and LRMC has a technical advisory contract with the French public transport authority (Régie Autonome des Transports Parisiens; RATP) in Paris.

The Line was built to the LRT standard, which has a lower capacity than the MRT, and soon after its opening, the line ran into a transportation capacity shortage. Therefore, two transportation capacity expansion projects have been implemented so far with yen loans to increase the number of trains, improve existing facilities, and introduce new Japanese-made trains.

This support by the Japanese government contributed to the development of a stable transportation environment and increased demand. This has motivated the private sector to participate, and in 2020, Sumitomo Corporation invested in LRMC and participated in the urban rail O&M project.

A project to extend the 6.6 km of the southern section of MRT Line 1 is underway. The procurement of rolling stock, construction of a new depot, and renovation of existing facilities for the extension are being carried out as part of a yen loan project by JICA. The procurement of rolling stock is being carried out by Mitsubishi Corporation and a Spanish company using Japanese equipment, and the construction of the depot is being carried out by Shimizu Corporation.

2) Effects of JICA Assistance

JICA assistance, such as transportation capacity expansion, has led to an increase in transportation capacity and an increase in the number of passengers. In addition, RATP, a technical advisor, has been assisting LRT Line 1 with technical issues, and as a result, internal regulations and manuals are presumably being enhanced. It is expected that the Japanese assistance will also improve the capacity to maintain these documents.

JICA's support to the development of a stable transportation environment and the expansion of demand, as well as advisory support from operators with high technical capabilities, have contributed to the reliable operation of the railway business, which led to Sumitomo Corporation's participation in the urban railway O&M business through its investment in LRMC.

(2) Manila MRT Line 3, Philippines

1) Outline

MRT Line 3, which opened in 1999, is a 16.8km with 13 stations, average daily ridership of approximately 200,000 (December 2021), and fare revenue of 650 million Philippine pesos (approximately 1.3 billion yen in 2020 *calculated at 1 Philippine peso = 2 yen).

The assets are owned by the Metro Rail Transit Corporation (MRTC), and O&M is performed by the Department of Transportation (DOTr) (some maintenance work is outsourced, see below).

In 1997, Sumitomo Corporation signed an EPC (Engineering, Procurement, Construction) contract with MRTC, and the Mitsubishi Heavy Industries Group executed the civil works, depot, station building, and track work, while a Czech company was in charge of rolling stock. Export credit was also provided by the then Export-Import Bank of Japan (JEXIM) and the Export-Import Bank of the Czech Republic, and the line opened in 1999.Operations were conducted by the Department of Transportation and Communications (DOTC, then reorganized as DOTr in 2016), and maintenance was contracted to a Japanese consortium of Sumitomo Corporation and Mitsubishi Heavy Industries, Ltd. from the start of operations until 2012, following the EPC

contract.

The maintenance work by the Japanese consortium was discontinued in 2012 due to DOTC's policy of cutting maintenance costs. After the discontinuation, companies from other countries that had signed contracts with DOTC were to perform maintenance work, resulting in a decline in vehicle utilization rates and frequent breakdowns and accidents. This led to an urgent need to rebuild the rehabilitation and maintenance system. Therefore, in 2018, a Japanese consortium of Sumitomo Corporation and Mitsubishi Heavy Industries, Ltd. was again awarded a contract from DOTr for rehabilitation and maintenance work as a yen loan project. This work is scheduled for completion in July 2022.

2) Background and Effect of JICA Assistance

In the early days, Japanese companies were deeply involved in the project, including EPC and maintenance work under contract, partly due to the provision of Japanese export credit.

Later, companies from other countries, including Philippine companies, took over maintenance contracts from Japanese companies, resulting in problems in dealing with aging systems, procurement of maintenance parts, and other issues, which led to a decline in vehicle utilization rates and frequent breakdowns and accidents.

In order to resolve the situation, JICA provided support, and Sumitomo Corporation and Mitsubishi Heavy Industries re-entered the project to provide high-quality rehabilitation and maintenance services to ensure the stable operation of the system.

2.5.11 O&M Projects in Other Sectors: Maritime (Handbook P79-P80)

(1) Outline

1) Lach Huyen Port, Vietnam

Lach Huyen Port has a two-tiered system that utilized yen loans for building a part of its infrastructure. For construction, land reclamation and ground reinforcement used yen loans, while container yard construction and the procurement of cargo handling machinery and other requirements were paid for with private-sector funds. Since 2018, Haiphong International Container Terminal (HICT), a special-purpose company (SPC) funded by a local public corporation and a Japanese company, has managed port operations. Primary revenues come from cargo handling services, storage services, and barge services.

2) Myanmar International Terminal Thilawa, Myanmar

Thilawa Multipurpose International Terminal has a two-tiered system that utilized yen loans for building a part of its infrastructure. A Japanese company that was the higher organization acquired the operating rates in 2018 and concluded a 38-year concession agreement with the Myanmar Port Authority. Later, a local public corporation, a local private enterprise, and a Japanese company jointly funded the establishment of Thilawa Multipurpose International Terminal (TMIT) and operations commenced in 2019. Primary revenues come from cargo handling services and storage services.

3) Sihanoukville Autonomous Port, Cambodia

Sihanoukville Autonomous Port has received continued JICA support to assist with repairs and expansions to the existing port, the construction of a new terminal, and the procurement of cargo handling machinery. The port is managed by the public company of the same name, Sihanoukville Autonomous Port. In 2017, JICA obtained a portion of shares. Later, JICA transferred its shares to a Japanese company. Primary revenues come from cargo handling services, storage services, and port fees.

(2) How to utilize for JICA projects, and points of attention

Below are the lessons learned from the port and harbor sector that are applicable to the railway sector.

1) Common lessons with the railway sector

- There are cases where Japanese companies expand overseas with the support of the Japanese government.
- High Packaging of construction and operation by Japanese loans encourage the entry of Japanese companies.

2) Differences with the railway sector

- Profitability allows operators to take on demand risks.
- Regulations are governed by market principles and the balance between supply and demand.
- Manualized and simple tasks provide a conducive training environment.
- Using a third country's training to train personnel lowers the risk of a delayed opening. This point could also be applicable in the railway sector.

2.5.12 O&M Projects in Other Sectors: Aviation (Handbook P81-P82)

(1) Outline

1) Wattay International Airport, Laos

Vientiane Wattay International Airport was built with yen loans to expand the international terminal building, and to build a new domestic passenger terminal building and peripheral facilities (including parking, roads on the property, and taxiways). Lao-Japan Airport Terminal Services (L-JATS), funded jointly by a Japanese company and the Laos Airports Authority, operates the airport. A Japanese company has been involved in operations for the more than 20 years since the airport commenced operations in 1999. A further 10-year extension was agreed to in 2019. Primary revenues come from ground handling services, passenger handling services, and tenant shop rents.

2) New Ulaanbaatar International Airport, Mongolia

New Ulaanbaatar International Airport was built with yen loans to construct the passenger terminal building, runway, control tower, and other facilities. The airport opened in 2021. The company New Ulaanbaatar International Airport (NUBIA), jointly funded by a Japanese company and the Mongolian government, operates the airport under a 15-year concession agreement. Primary revenues come from ground handling services and passenger handling services.

3) Mandalay International Airport, Myanmar

Mandalay International Airport is a case of an airport operated by a Japanese company with very little involvement by the Japan government. MC-Jalux Airport Services (MJAS), jointly funded by a Japanese company and a local private company, has been operating the airport under a 30-year concession since 2015. Primary revenues come from ground handling services and passenger handling services.

(2) Key Points for JICA Project Utilization

Below are the lessons learned from the airport sector that are applicable to the railway sector.

1) Common lessons with the railway sector

- Infrastructure development should be covered by Japan ODA loans.
- To ease the market entry of Japanese companies, the proactive support of the Japanese government through bilateral assistance schemes is effective.

2) Differences with the railway sector

- Local knowledge exists for airport O&M.
- Airport O&M works are not as complex.
- If maintenance and management duties can be simplified as much as possible and there is similar knowledge about operating routes in the country receiving assistance, then from a long-term perspective, it should be possible to simplify personnel training in the railway sector, as well.

2.5.13 O&M Projects in Other Sectors: Road (Handbook P83-P84)

(1) Outline

1) India Highway, India

Cube Highways, the operating entity of India's highways, is funded by institutions from multiple other countries. In 2017, an agreement was reached for Japanese companies (Mitsubishi Corporation, NEXCO East, JEXWAY, and JOIN) to obtain 20% of shares. Later, in 2019, Cube Highways received up to US$8.5 million in funding from Japan Infrastructure Initiative (JII), as well as up to around 3 billion yen in additional funding from JOIN. Furthermore, NEXCO East and JEXWAY included a technical advisory agreement with Cube Highways to provide technical assistance services. Primary revenues come from tolls.

2) Bintaro-Serpong Toll Road, Indonesia

The majority of shares in PT Bintaro Serpong Damai (BSD), the operating entity of Bintaro-Serpong Toll Road, is owned by PT Margautama Nusantara (MUN), whose parent company is PT Nusantara Infrastructure Tbk (NT). In 2013, Japanese companies (NEXCO West and JEXWAY) concluded a memorandum of understanding with NT concerning cooperation with a business entry study. In 2014, NEXCO West and JEXWAY obtained 4% of BSD shares. In addition, the companies concluded with MUN a memorandum of understanding on comprehensive technical coordination in 2015, and now utilize the maintenance knowledge and technology accumulated in the highways business to provide technical advice according to local needs. Furthermore, in 2020, JOIN also provided funding and obtained 10% of MUN shares, of which BSD owns the majority. Primary revenues come from tolls.

(2) Key Points for JICA Project Utilization

The road sector and the railway sector have many points in common. Below are the points in common and lessons learned from the road sector.

- The setting of fares and toll fees tend to depend on political prerogatives rather than market principles.
- Issues in O&M personnel training are entrenching trained personnel and passing on skills.
- The proactive support of the Japanese government within the bilateral assistance framework to ease the market entry of Japanese companies is effective.

Chapter 3 Past Support Projects

3.1 Mumbai Metro Line 3, India (Handbook P89-P90)

(1) Outline

Table 3-1 Summary of Mumbai Metro Line 3

Implementing Entity/ Operating Entity	MMRC（Mumbai Metro Rail Corporation）/ MMRC（Planned）
Funding	Government
Total Planned Project Cost	Approx. 520 billion JPY（Approx. 340 billion INR）
Total Line Length	34km（All Underground）
No. of stations	27

(2) Project Characteristics

Figure 3-1 shows the progress of the Mumbai Metro Line 3 project. India already had a certain amount of experience and results with domestic urban railway O&M, such as the Delhi Metro, as well as laws pertaining to urban railway O&M. In addition, as in the many cases of consultants directly hired by the government implementing plans and designs in India's urban railway projects, JICA did not perform the FS for Mumbai Metro Line 3. Although considerations about O&M organization could have been carried out with Japanese assistance, possibly involving a private enterprise, rather than pressing for a decision during the study, it was only provided as an option. Japanese assistance was taken under separate consideration regarding O&M support services in the opening preparation stage.

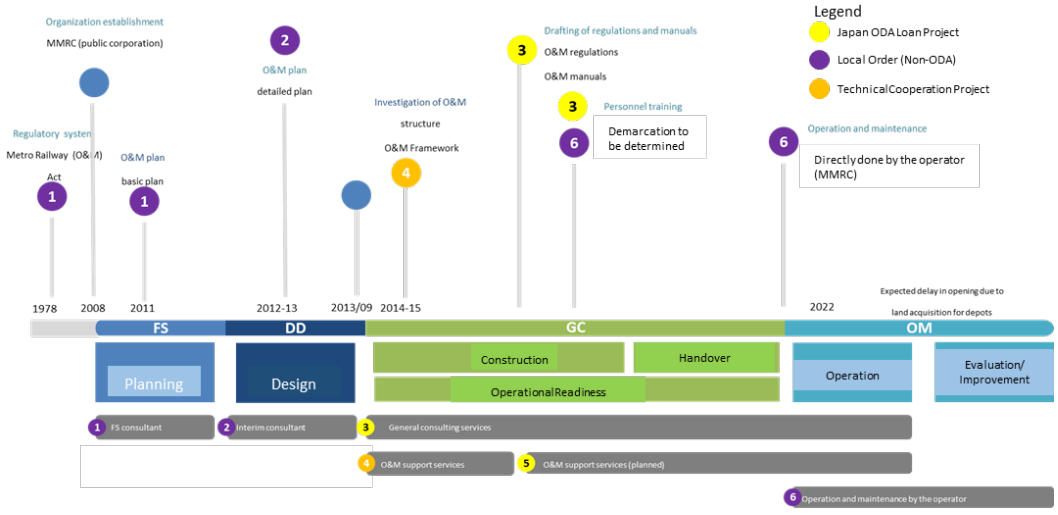


Figure 3-1 Progress of the Mumbai Metro Line 3 Project

(3) General Comments

In the FS consultant stage, O&M support was largely not performed. Considerations about construction preceded O&M considerations. In addition, the organization for O&M organization-building support was not finalized. The lack of confirmation about the framework for the implementing and operating entities created uncertainty about the scope of O&M support in the GC stage. This is one reason to include O&M organization-building within the scope from the planning and design stage.

In addition, there were cases seen in which O&M support was lacking in the GC stage, as consultants had little recognition of the need for O&M support and devoted many resources to construction. The

cause is believed to be a lack of understanding about O&M because a civil engineering expert is typically placed at the top for GC. If O&M support were included during GC, sufficient resources should be ensured during considerations of the support scheme.

3.2 Dhaka MRT Line 6, Bangladesh (Handbook P91-P92)

(1) Outline

Table 3-2 Summary of Dhaka MRT Line 6

Implementing Entity/ Operating Entity	DMTC（Dhaka Mass Transit Company）/ DMTC
Funding	Government
Total Planned Project Cost	Approx. 370 billion JPY（Approx. 280 billion BDT）
Total Line Length	20km（All Elevated）
No. of stations	16

(2) Project Characteristics

Figure 3-2 shows the progress of the Dhaka MRT Line 6 project. This first attempt at such a project was unprecedented because laws for overseas railway projects were produced from scratch. Loan assistance experts were provided via the "Consultants to Help Strengthen the Implementation System of the Dhaka City High-Speed Rail," "legal setup consultant (LSC) for Dhaka Mass Transit," and other project management frameworks that caused no harm for the Japanese company business environment, thus establishing laws for technical standards. In addition, in the construction stage, GC was complemented with the Institutional Development Consultant (IDC) who formulated financial and business plans. To strengthen administrative management in the urban railway sector, similar efforts will likely be rolled out in other countries in the future.

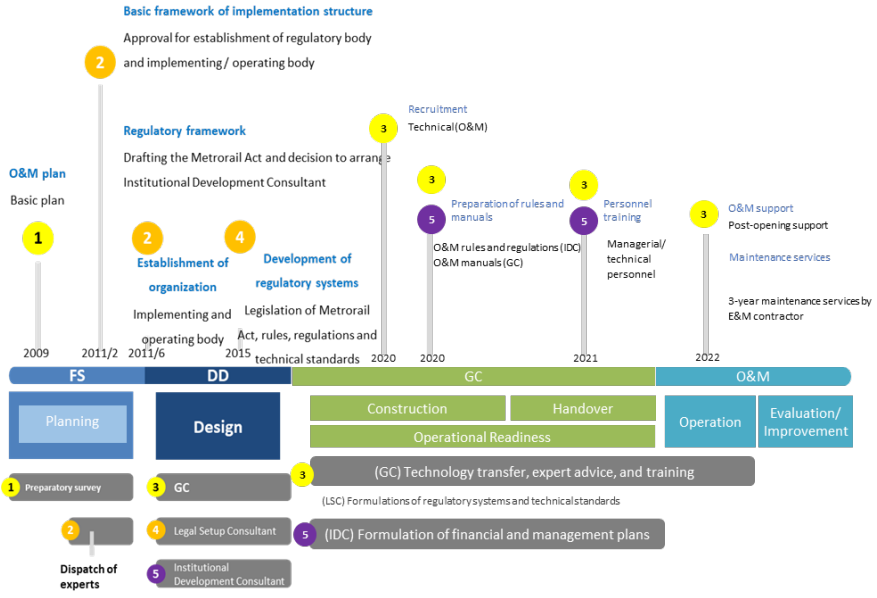


Figure 3-2 Progress of the Dhaka MRT Line 6

(3) General Comment

The Dhakka MRT Line 6 project was carried out smoothly through unified implementation with consistent support from the country's government. In addition, the dispatch of experts organized a support framework in the project implementation stage. Furthermore, the clear division of tasks among general contractors, organizational development, and legal preparations prevented overlapping scopes. However, while focusing on design and construction work, a point requiring attention is the possibility that organizational development support coming too early could reduce the support effect while not

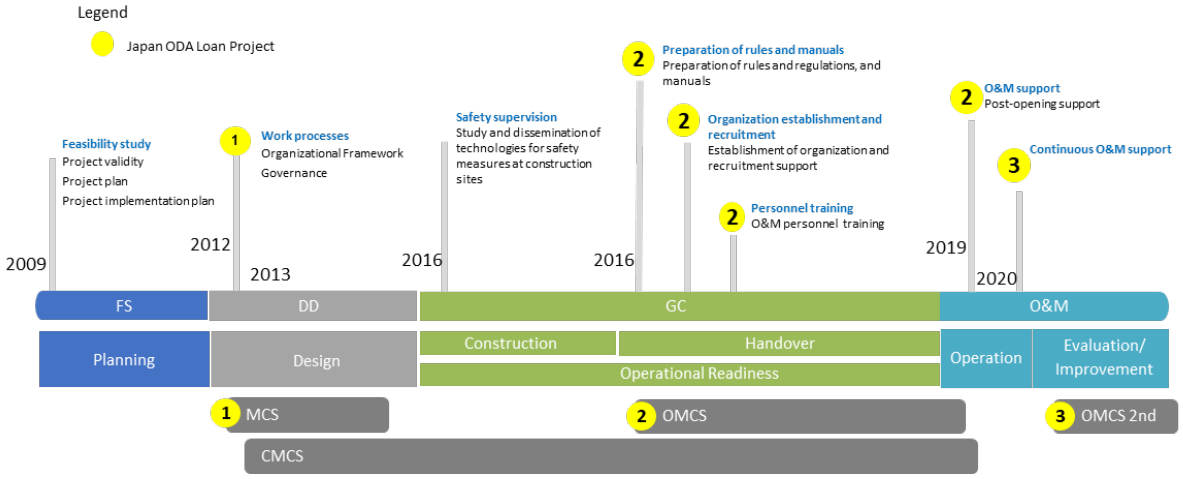
deepening considerations.

3.3 MRT Jakarta North-South Line, Indonesia (Handbook P93-P94)

(1) Project Characteristics

Support projects have been created to conform to each stage, contributing to the sound management of the business upon and after opening. Figure 3-3 shows the progress of the Jakarta MRT North-South Line project.

A wide range of support was provided through the OMCS, including the creation of rules and manuals, organization establishment and recruitment, personnel training, and O&M support immediately before and after opening.



CMCS: Construction management consulting service

MCS: Management consulting service

OMCS: Operation and Maintenance consulting service

OMCS 2nd: OMCS 2nd stage

OSV: On-Site Visualization

Figure 3-3 History of yen loan projects, etc. on the MRT Jakarta North-South Line

(2) General Comment

- As for O&M, from the March 2019 opening to 2021, there was no major hindrance to transport arising from business operator responsibilities. When a major blackout occurred in the Jakarta area in August 2019, the safe evacuation over one hour later of some 3,400 passengers from a seven-car train, as well as a four-car train that stopped between stations, was well received.
- Construction works of new railways are prone to delays, and the government normally sets the opening dates. Given this, it is necessary to synchronize the period and support activities of consulting services accordingly. This project was completed through the collaborative efforts of the OMCS, CMCS, and all the contractors.

3.4 Ho Chi Minh Line 1, Vietnam (Handbook P95-P96)

(1) Overview of Ho Chi Minh Line 1 Project

JICA has conducted "The study on the Urban Transport Master Plan and Feasibility Study in HCM Metropolitan Area" (HOUTRANS) since 2000. The report recommended the construction of a route that includes a segment that later became Line 1. After that, support with a yen loan to construct Line 1 in 2007 resulted in the conclusion of an agreement the following year that included the line's construction.

Technical cooperation projects are generally carried out in two phases. Phase 1 was the Project for Support on Setup of Operation and Maintenance Company of Urban Railways in Ho Chi Minh City (TC Phase 1), carried out from 2011 to 2013. The counterpart was the preparation unit for setting up the O&M Company (PUC) established by the Management Authority of Urban Railways (MAUR). Phase 2, the Project for Support on Setup of Operation and Maintenance Company of Urban Railways in Ho Chi Minh City (TC Phase 2), spanned five years beginning in 2017. Support covered not only the production of O&M rules and manuals, hiring, and personnel training, but also included commercial facilities and mobility management.

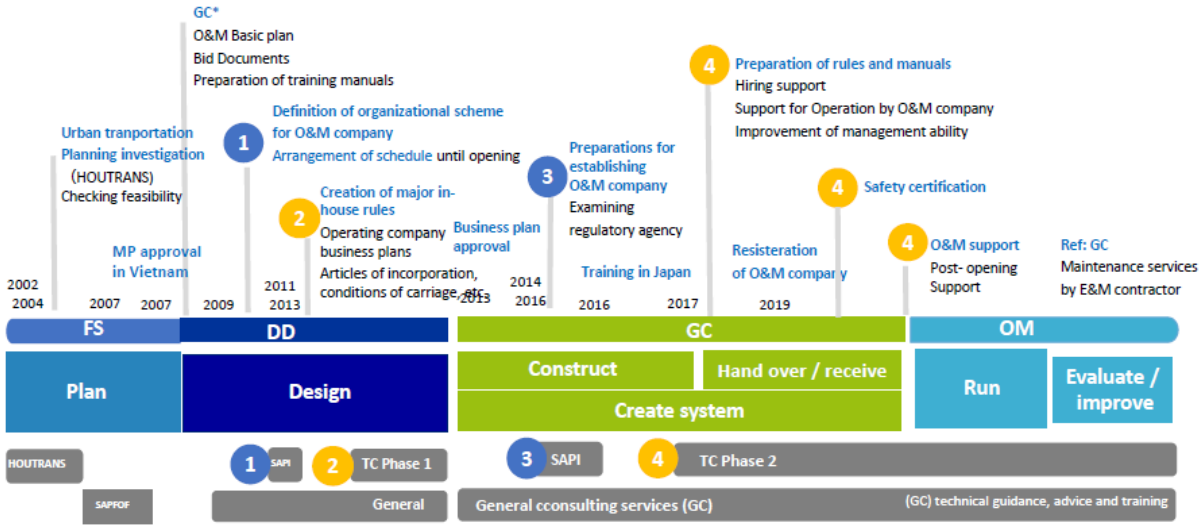


Figure 3-4 Support Workflow for Ho Chi Minh Line 1

(2) Project Achievements and Challenges

The main results are below.

• The O&M company's business plan and articles of incorporation were approved and the O&M company, HCMC Urban Railways Company Limited No.1 (HURC1), was established.

• Some manuals were completed. They were made from basic rules concerning conditions of carriage, safety, personnel, and finances.

• Training was conducted locally in Japan. Some conductor training (carried out by the GC) started.

Meanwhile, there are issues concerning counterpart autonomy and division of duties with the GC and contractors.

Although counterparts would ideally have the autonomy to carry out duties on their own after opening, due to their lack of urban rail experience and low competence in decision-making, it is often difficult for them to make prompt decisions.

Regarding the division of duties, as an example of the close relationship with the division of duties presided over by TC2, there are manuals for workers on-site and manuals for handling equipment, but since the GC and contractors, who are not parties to the agreement, are in charge, there needs to be

proper coordination and sharing with the GC and contractors about the work's progress in TC2.

In addition, due to construction delays owing to Vietnam's government finances and the COVID-19 pandemic, the opening may be postponed to 2023 or later.

3.5 Metro Manila Subway, Philippines (Handbook P97-P98)

(1) Outline

Table 3-3 Summary of Metro Manila Subway

Implementing Entity/ Operating Entity	DOTr（Department of Transportation）/ TBD
Funding	Government
Total Planned Project Cost	Approx. 800 billion JPY（Approx. 360 billion PHP）
Total Line Length	27km（Underground 26km、Elevated 1km）
No. of stations	15

(2) Project Characteristics

Figure 3-5 shows the progress of the Manila subway project. The ADB OPPP office hired by DOTr provided bidding support for the selection of private sector O&M operators by tender. Very few of the conditions were specified by the state through national legal systems or regulations, and most of them were stipulated in the O&M concession contracts. At the design stage, support for the establishment of training centers was provided in parallel, and a human resources development system was established at the same time as the establishment of training centers.

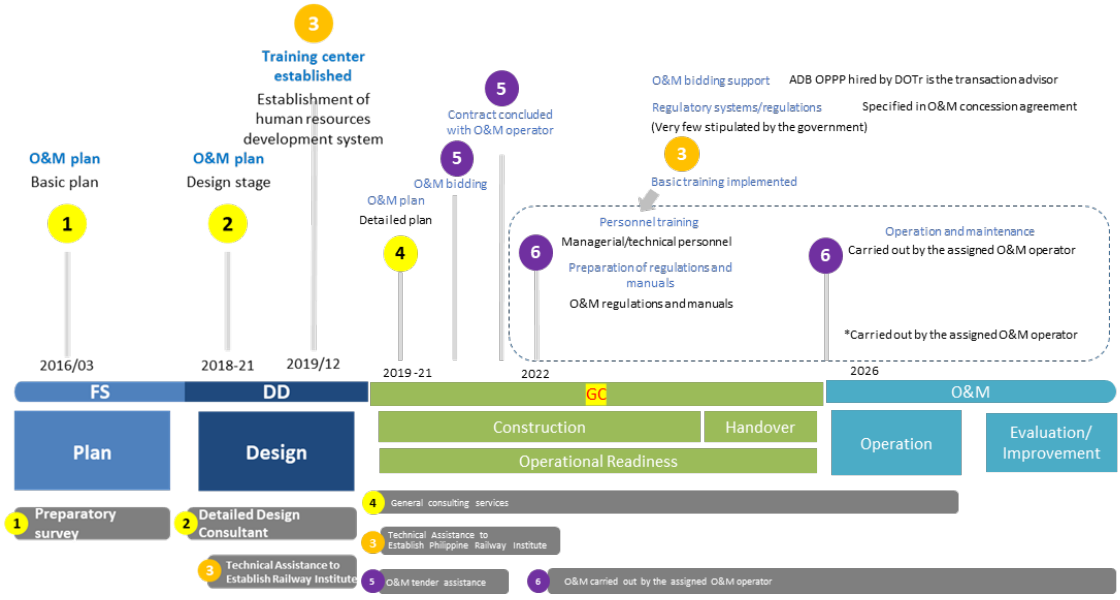


Figure 3-5 Progress of Manila subway project

(3) General Comment

Extensive support was provided, such as a wide range of design studies, business approval process support and human resource development support, and results were achieved in terms of planning and design.

However, as a result of this extensive support, the number of stakeholders has increased and coordination between projects has become extremely complex. It is recommended that there should be careful planning and design of the overall structure of support and the coordination mechanisms between the support projects at the preparatory survey stage, rather than responding appropriately as the project develops.

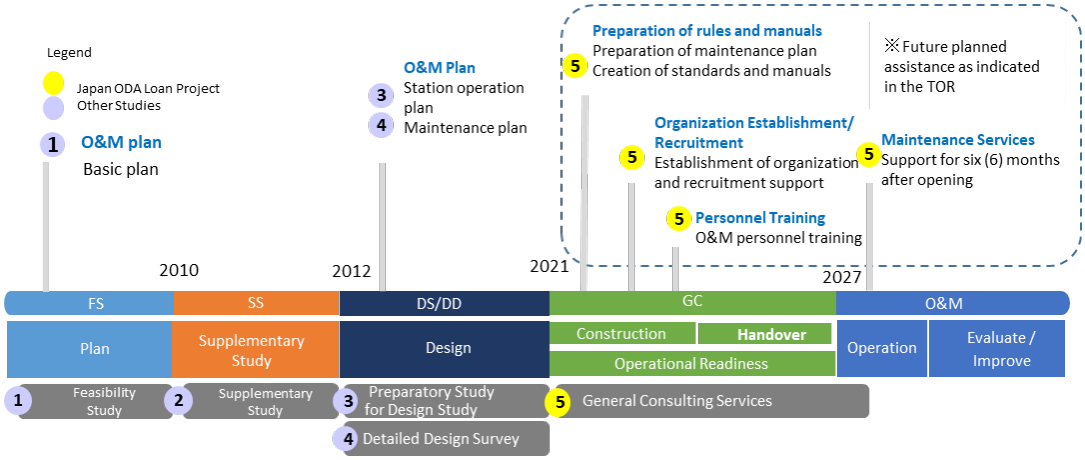
The policy of the implementing agency is to conducting bids for O&M operators at the design stage, but it is difficult to determine bid conditions without waiting for the design to be finalized, and it is difficult to forecast the business starting date. In addition, other donors (ADB OPPP) are supporting O&M companies' procurement activities, making it difficult to reflect the intentions of JICA, which is a donor of construction projects. In the ODA loan project, JICA should also clarify its own criteria for the selection of O&M operators.

Furthermore, the legal systems to deal with urban railways have not yet been fully established in the Philippines, meaning that each line had to be handled separately, by directly management or concession contracts with private sector companies. In the railway business, which has a level of high public interest, it may be said that the national government needs to improve the legal system and regulate it in a unified manner, rather than dealing with each line separately.

3.6 Greater Cairo Metro Line No.4, Egypt (Handbook P99-P100)

(1) Project Characteristics

The F/S of the entire Line 4 was carried in 2009, transitioning to the supplementary survey (S/S) of the Phase 1 section from 2010. In response to these results, in September of 2010, the Egyptian government requested an ODA loan under the Japanese Special Terms for Economic Partnership (STEP), and the project was scheduled to be implemented by providing an ODA loan. As regards the main components of the project, a technical standards plan preparatory survey and detailed design survey have been carried out, with the bidding and construction management stage beginning from 2021. (Figure 3-6 shows the progress of the project.)



Source: Study Team

Figure 3-6 Progress of the Technical Cooperation Project for Cairo Metro Line No.4

(2) Project Achievements and Challenges

1) Achievements

In the detailed design survey, it is assumed that the ECM will be responsible for O&M. Given this, the formulation of the basic plan for operations was based on their existing O&M systems. The basic plan description of the detailed conditions in the drawings and specifications for the tender.

In addition, regarding E&M manuals, the specifications clearly stated that the sub-contractor should prepare the necessary ones, and preparations were made to facilitate a smooth opening.

With regard to the trial run before taking over, a degree of caution is required because the locus responsibility will be unclear, and in this case, the trial run (Demonstration) for performance confirmation and the crew training (Experimental Working Period) are clearly separated. This was organized in this way so that no problems would occur in the period before and after the opening.

2) Challenges

Construction works have been delayed due to the results of the geotechnical surveys in the vicinity of the Nile River. The schedule of opening has been postponed to 2027. Since the ECM will be working with Japanese signaling equipment for the first time, it is necessary to conduct thorough training, as well as pay close attention to whether the maintenance of the said equipment is aligned or compatible with the entity's existing maintenance practices.

This was not a business contract in which the local government or the business operator are the ordering party, using a ODA loan, but was a project in which JICA was the ordering party, in the same way as the former collaborative D/D (detailed design) method.

3.7 Provision of assistance in the future (Handbook P101-P102)

(1) O&M Planning Standards (FS Stage)

The essential areas and depths of study for O&M as minimum requirements in the conduct of the FS are indicated. Ideas for the effective conduct of FS (e.g., the composition of the study team and items reviewed by railway operators), are incorporated.

- Minimum requirements in the conduct of the FS are indicated to define the depths of study for O&M.
- Assignments and tasks of Railway O&M experts are described.
- It is recommended to embody the review structure in the FS stage, where members from railway operators check any omissions in O&M support and essential areas of study.

3.8 Planning and Implementation of O&M support Programs (Handbook P103-P108)

(1) Planning of O&M Support Programs

The key points in planning for O&M support in the FS Stage are described. The checklist and the standard framework for O&M support help eliminate overlooked items during the implementation stage. The implementation framework and project scheme are the basis for designing O&M support programs.

1) O&M Support Checklist

The sample framework is prepared to highlight the standard items necessary for future O&M support, including post-opening assistance. Standard items include; O&M plan, personnel and organizational plan, business plan, economic and financial analysis, regulatory system, contracts, organizational development and recruitment, operational readiness, post-opening support and training center.

- The O&M support checklist has been prepared and organized through the analysis of past TORs.
- The list is used to identify which entity can best provide the corresponding assistance when defining the support framework.
- In addition to the consulting packages, it is important to be aware of the sharing and delineation of roles with the implementing body, the operating entity, and the contractor.

Use of the checklist should be in the following manner.

- Consultants propose each consulting package and TORs at the FS stage.
- JICA checks if there are any overlooked items in the O&M support.
- JICA formurates the O&M support programs along with the construction project.
- Consultants carry out O&M support programs according to the TOR.
- JICA supervises the works of consultatns by continous use of the checklist.

2) Concept of Support Framework

The GC, OMCS, or contractor should be in charge of carrying out capacity building activities for different personnel (e.g., managerial capacity building for head office personnel, on-the-job training for worksite personnel, and user training for equipment handling). In addition, post-opening support should be programed effectively, as several projects in the past required such interventions.

3) Planning of Support Framework

The O&M support framework is determined at the FS stage; and under this framework, the GC's scope of work for O&M must be made clear. In terms of organizational development, institutional development, and establishment of training centers, the implementing entity and the JICA must agree as to whether these scopes should be within separate consulting packages or part of the GC. Parties should also agree as to whether these will be carried out through a Japan ODA loan or as a technical assistance project. While various support programs can be explored for public operator models, support from the JICA may be less for private operator models.

4) Standard form of Support Framework

O&M capacity is built with a variety of support activities in addition to GC and contractors. These include assistance with regulatory systems and technical standards, business plans, operational readiness, and post-opening support. A comprehensive framework of O&M support in countries with little or no experience in urban railways is indicated. The support package will be decided through the preparatory

survey done at the FS stage, taking into account the local and market contexts of the railway sector.

5) Implementation Structure

The JICA's preparatory survey should identify which entity is viable to act as the operating body. The entity, however, is often not made clear at the FS stage. Project schemes usually require high-level executive decisions made as the result of extensive stakeholder coordination. If several alternatives for the implementing structure needs to be studied in detail a project scheme expert should be assigned to the O&M of the study team.

(2) Implementation of O&M Support

1) GC Team Composition

The GC O&M support team is involved in three work groupings: preparation of O&M manuals and training plans, interface (I/F) coordination between GC's O&M plan with the contractor, and development of the business scheme and/or business plan. Since the assignments of GC O&M support will depend on other programmed O&M support, whether TA or OMC is in place, presented below is an enumeration of expert positions, tasks, and other important information. Note that add to these, expertise in common ticketing systems, office IT systems, and asset management may be added, as needed.

2) O&M related OMC Personnel Composition (required specialist fields)

Experts dispatched for the Jakarta MRT's OMCS (for field operations supported by Japan ODA Loan), as well as Technical Cooperation Project for the Ho Chi Mind City Railway Line 1 (head office management support), are enumerated, respectively.

3) Preparation of Manuals, Rules, and Regulations

O&M manuals are finalized based on submissions of the contractor. O&M rules and regulations are prepared jointly by the contractor and the operator. Based on past experiences, the consultant assisting the operator may find difficulty receiving the contractor's submissions at the right time, usually due to contract terms. In such cases, the recourse for the consultant is to prepare relevant documents based on their assumptions, leaving out necessary inputs from the contractor. Developing standard documents to improve the efficiency of consulting services will help avoid these scenarios. It will also enable consultants to devote more effort to practical training for O&M personnel.

4) Capacity Building

Capacity building will be more effective by placing multiple C/Ps in each field of discipline, mandating the practice of thorough reporting by C/P, and allocating dedicated training experts. There have been cases where the capacity building became less effective due to different factors (e.g., C/P turnover and reassignment, excessive reliance on expatriate experts for progress reporting, and lack of training experts for practical training). In line with this, the technical assistance project should clearly state the above requirements in the Record of Discussion (RD). Note however that in the case of ODA Yen Loan Projects, there can be instances wherein the terms and conditions under the OMCS contract may contradict the above requirements.

5) Ideal Conditions Before O&M Support

Decisions as to the overall implementation framework and project scheme should ideally be determined before the provision of O&M support. Determining the necessary amount and expertise for the O&M support is difficult if the framework of the implementing and operating entities is not confirmed at the FS stage. Choices as to whether O&M will be done in-house or outsourced, and whether the

implementing entity or a newly established organization performs O&M should likewise be established before the conduct of O&M support. Note, however, that these precedent conditions are not always possible, as there are instances when actual decision-making powers are well beyond the authority or mandate of the implementing agency.

6) Timeline for Operational Readiness

Even as O&M support is programmed based on the project timeline, delays in construction schedules often necessitate substantial adjustments. Therefore, conditions to start and resume O&M support activities should be made clear in advance. Prime examples of operational readiness timelines include that of the Tsukuba Express in Japan and the Jakarta MRT in Indonesia, as these encountered no critical delays in commissioning. If the schedule is delayed or likely to be delayed, the implementing entity and JICA should see to it that conditions for resuming O&M support are met (e.g., O&M company establishment and personnel recruitment) such that the support is optimized and will not go idle. If support is extended with the minimum number of experts, JICA may need to consider a review of resources for the follow-up period and corresponding compensation for consultants for foregone opportunities.

7) Stakeholder Coordination

All key stakeholders should be involved during stakeholder coordination activities in project management. In most cases, there are similar stakeholders for railway construction projects and O&M support activities. On the technical side, provisions for uninterrupted power supply and dedicated frequency bands for communication systems are often raised as issues. Additionally, authorities that have jurisdiction over the state-owned enterprises and/or civil servants can get involved in cases wherein a public sector entity is the operator of the railway.

8) Project Effectiveness and Evaluation

Per JICA's guidelines on project effectiveness/evaluation, additional indices may be required to measure O&M performance, this includes the number of service suspensions, system failure rates, and the number of serious accidents as operational indices. Benchmarks for carbon emission reduction and gender mainstreaming can also be used as effect indices.

The way forward to enable the above should be as follows:

- JICA incorporates the above indices to the "Operation & Effect Benchmarking Guideline".
- JICA reflects the above indices in the TORs for the preparatory survey in FS stage.
- Consultants develops the above indices in the report of preparatory surveys.
- JICA confirms the above indices are properly described in the report.
- JICA specifies the requirements for the consultants to refer to the above indices in the O&M support programs.
- Consultants for the O&M support programs updates the above indices.
- JICA confirms the above indices are properly updated in the O&M support program.

3.9 Different Formats of Technical Cooperation (Handbook P109-P110)

The features and scopes of the different technical cooperation schemes are summarized herein. Several ideas for overseas training in third countries are also highlighted. Precedent case studies are useful to meet the different needs for future O&M support activities.

(1) Characteristics of Each scheme / Arrangement of O&M Support

Technical assistance projects are suitable for capacity building including the establishment of an O&M company. On the other hand, project implementation assistance aims to provide support in developing regulatory systems, technical standards, and business plans. Furthermore, the dispatch of experts should contribute to the formulation of these support programs.

(2) Overseas training in Third Countries

Taking advantage of existing and operational lines and training centers, the JICA can arrange overseas training opportunities in third countries for implementing agencies who are implementing or are intending to implement urban railway development and O&M projects. Effective training programs can be arranged involving previously implemented projects in third countries carried out as JICA Technical Cooperation and ODA Yen Loan Projects. Destinations are chosen according to the training objectives and the characteristics of each urban railway as shown below. Since the JICA provides a wide range of O&M support to many cities and countries, training on various subjects can be offered.

Selection of destinations should take into accout; similarity of O&M scheme (inhouse / outsource), vertical profile (elevated / underground), electrification system, signalling system, and language.

(3) Support for Institutional Development and Formulation of Technical Standards

For countries unable to enforce control in the urban railway sector due to the absence of a regulatory system and technical standards, the JICA can facilitate assistance programs to enhance the results of project implementation and contribute to exporting Japanese railway systems.

(4) Safety Certification

Due to differences between Japanese and European “Safety Management System” (SMS), a special arrangement may be required to assist in safety certification. In most cases, the recipient country stipulates compliance with the local SMS, which is greatly influenced by the European approach through the law, or through the procuring party’s requirements in the tender documents. To be prepared for such cases, the JICA should further accumulate track records and expand resources.

(5) Training Equipment

The JICA can contribute to human resource development by providing support for the procurement and delivery of training equipment. Support is provided regardless of whether the project involves introducing new training facilities equipment along with new line construction or if the project involves repurposing an existing training center for urban railways. Training equipment includes driving simulators, mock-up stations, signal system diorama, and cut models of bogies and track structures. Also, JICA may offer training software with Digital Transformation/Virtual Reality technologies which have been developed by Japanese railway operators.

Chapter 4 Overseas Expansion of O&M

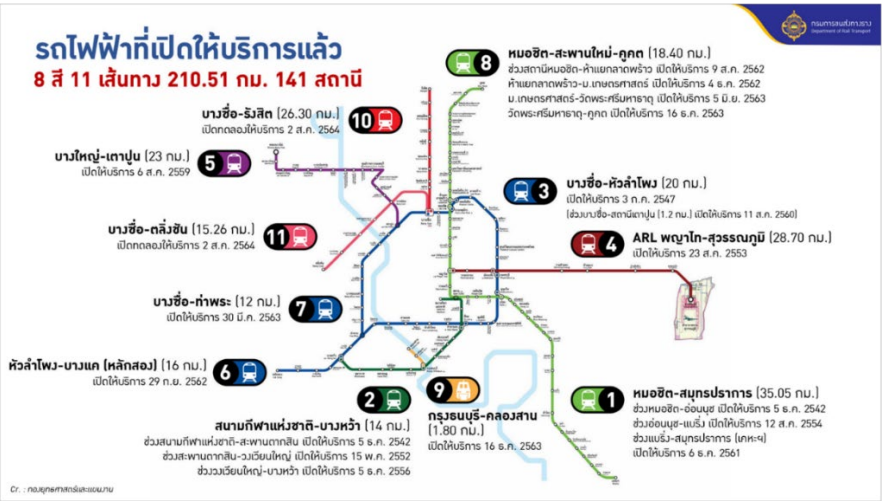
This chapter will describe the results of investigations that were conducted into the current situation, challenges and needs, etc., of railway O&M, mainly in Southeast Asian countries, seen as necessary in order to maintain safe and reliable railway operation as the core urban transportation system, and the policy direction of technical support based on these findings. Subsequently, the chapter will consider future support development for civil engineering maintenance.

4.1 Investigation of needs in developing countries

4.1.1 Bangkok, Thailand

(1) Current urban railway network in Bangkok

As shown in Figure 4-1, there are currently 8 urban railway lines, forming a railway network of approximately 210 km.



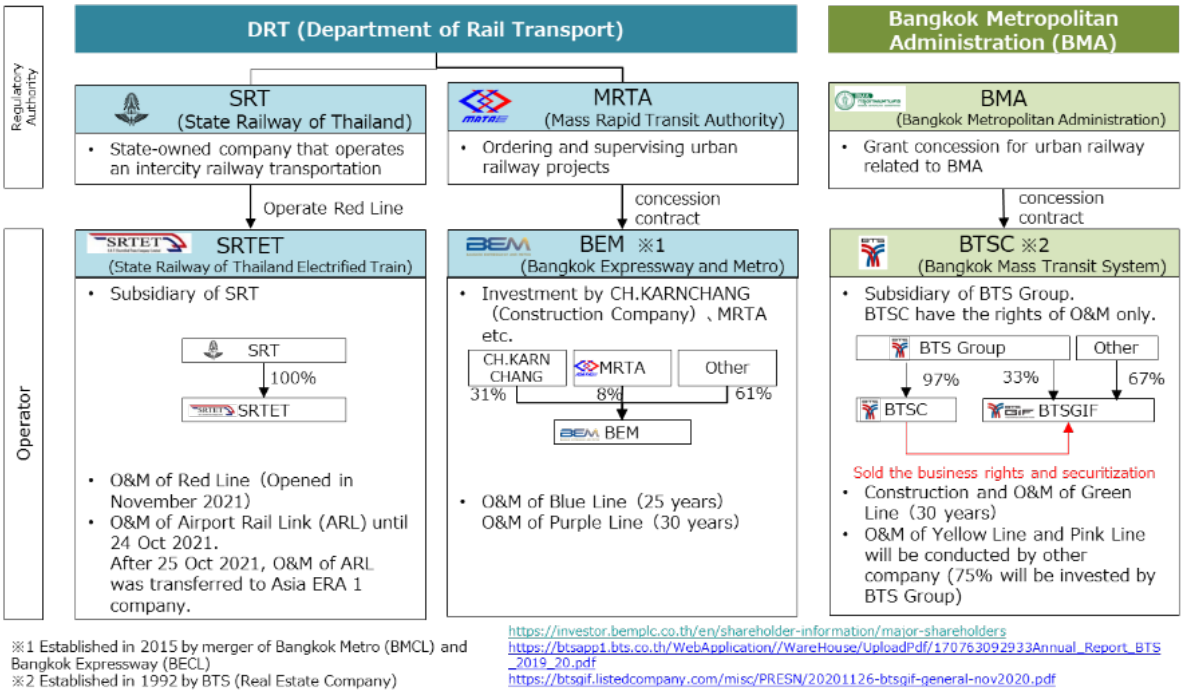
Source: Website of Ministry of Transport, Thailand[7]

Figure 4-1 Existing urban railway map of Bangkok（As of Nov, 2021）

(2) Regulatory bodies and operating entities of urban railway in Bangkok

The structure of the regulatory authority and operator is shown in Figure 4-2.

[7] https://www.drt.go.th/



Source: Study Team

Figure 4-2 Structure of Supervisory Authorities and Operating Entities of Urban Railway in Thailand

(3) Current Operational conditions, issues, needs and applicability of Japanese technology

JICA Study Team (JST) interviewed relevant organizations in Bangkok regarding the current conditions of operations, issues, etc. Based on the understanding of the JST, the main items are summarized in each table below.

Table 4-1 Results of Interviews with DRT

Items	Results
Issues & Needs	1. DRT i**s in the process of preparing laws, regulations, standards**, etc. related to railway business, O&M, etc. 2. DRT is considering **the future use of EVs and the electrification** of the SRT lines. 3. **Automated driving system** (Already implemented at Gold Line) 4. **Driver license management** methods (licensing system and training methods) 5. There is **no system for alternative transport service when operations are suspended, for refund procedures, and for collective payment of fares** across multiple railway operators.
JST view	1. DRT recognizes the need to develop laws, regulations, and standards, and is in the process of drafting them. 2. **The development of laws, regulations, and common system** (common fare, alternative transport service, etc.) **can't keep pace** with the rapid expansion of urban railway network.

Table 4-2 Results of Interviews with MRTA

Items	Results
Issues & Needs	1. MRTA is currently investigating ways to **accurately assess the operation status of railway facilities and rolling stock**. 2. **Many staffs are left** to advance their career. (Common challenge in the railway industry in Thailand).

Items	Results
JST view	MRTA has a need to introduce **new technologies** (Artificial Intelligence (AI), CBM, etc.) that will lead to **efficient KPI management**. **CBM: Condition Based Maintenance* *TBM: Time Based Maintenance (Conventional method, in contrast with CBM)*

Table 4-3 Results of Interviews with BEM

Items	Results
Issues & Needs	1. BEM asked about the revision of technical standards after the occurrence of natural disasters in Japan. (JST responded that there are revisions of technical standards by regulatory authorities.) 2. BEM has **a challenge in setting a standard for the useful life of electronic equipment overhauls** that will occur in the future. 3. Some parts are made in Europe and take time to be delivered.
JST view	BEM intends to **optimize equipment replacement cycles, parts procurement methods, and failure countermeasures**.

Table 4-4 Results of Interviews with SRT and SRTET

Items	Results
Issues & Needs (Head office)	1. In **Civil/ Track field**, there are facilities that are aging, deteriorating, etc., and are being addressed with short maintenance cycles. A management system is under construction for track maintenance. 2. In **Rolling Stock Field**, the challenge is to acquire knowledge both technologies related to carriages and bogies (safety, maintenance, and inspection tools) and the latest technologies.
Issues & Needs （Field Survey）	**1. Station Operation Field** Delay certificates are issued on paper basis of a size referring to Tokyo (previously A4 size). Paperless system is under consideration. **2. Technical Field (Common)** (1) **Regulations and manuals and the interpretative materials are inadequate** in some fields. (2) Lack of training on **detailed maintenance procedures**. (3) Insufficient consultation system **in case of problems after the DNP***. **DNP: Defects Notification Period or DLP: Defects Liability Period* 3. In **Rolling Stock Field**, there is **no drainage ditch in the car wash area** hence the equipment is unusable. (Wastewater is purified and discharged into the sewage system in Japan by law). In addition, the working space in the inspection pit is too narrow. 4. In **Electrical Facilities Field**, **signal cables have been cut or stolen** and failure condition continues.
JST view	1. SRT has shown great interest in **the new technology**. 2. They use manufacturer-developed standards for technical criteria for railway facilities.

Table 4-5 Results of Interviews with BTSC

Items	Results
Issues & Needs	1. Civil/ Track (1) BTSC is faced with **the challenge of securing human resources and budgets.** (2) BTSC is **willing to introduce BIM* and drones** into the civil field. **BIM: Building Information Modeling* 2. Rolling stock The oldest cars are over 20 years old hence car renewal is planned in 2022. The renewal includes in-car broadcasting equipment, LCD monitors, and air conditioning systems.
JST view	BTSC seem to have **a need for a maintenance system that utilizes the latest ICT technology, etc.**

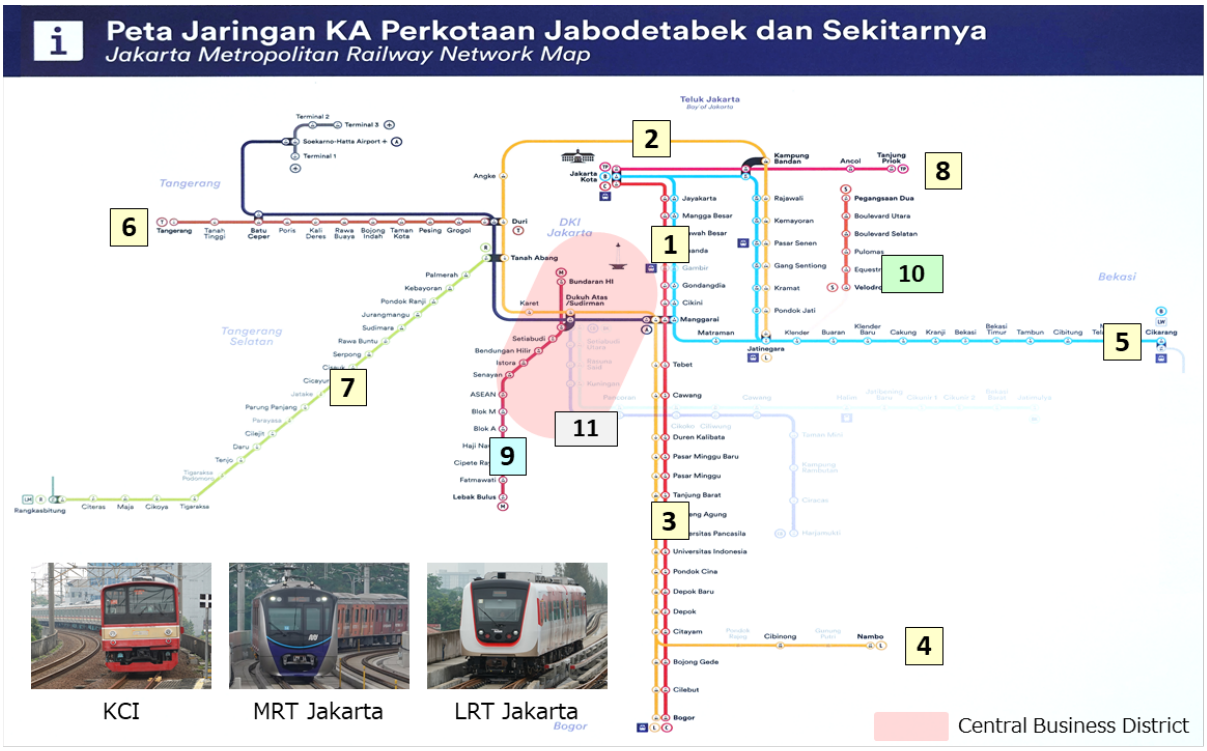
4.1.2 Jakarta, Indonesia

(1) Introduction

Jakarta's urban railway currently consists of ten lines run by three operators.

First, "KCI" (PT Kereta Commuter Indonesia) is an operator that runs eight lines. Starting with the introduction of Japanese made trains (new rolling stock) in 1976, and the modernization of plant and equipment based on the Jakarta Metropolitan Railway Transportation Plan Survey conducted by JICA in 1981, Japanese ODA loans have been funding improvements in the transportation system. In 2000, the transfer of used Japanese rolling stock by Tokyo Metro and other began, and this has continued to contribute to the elimination of congestion due to lack of transportation capacity to this day.

Next is "MRT Jakarta", operating one line. Comprehensive support was provided from Japan, from construction to the opening, and in March 2019, it opened as Indonesia's first subway. In addition, "LRT Jakarta", which opened in December of the same year, also operates one line and that was built with technical support from South Korea.



No.	Operator	System	Line Name	Section	Length (km)	Station No.
1	KCI	Commuter rail	Central line	Jakarta Kota～Manggarai	9.9	8
2			Circle line	Manggarai～Jatinegara	25.4	14
3			Bogor line	Manggarai～Bogor	44.9	17
4			Nambo line	Citayam～Nambo	16.2	3
5			Bekasi line	Manggarai～Cikarang	34.2	13
6			Tangerang line	Duri～Tangerang	19.3	11
7			Serpong line	Tanah Abang～Rangkasbitung	72.8	19
8			Tanjung Priok line	Jakarta Kota～Tanjung Priok	8.1	4
9	MRT Jakarta	MRT	North-South line	Lebak Bulus～Bundaran HI	15.7	13
10	LRT Jakarta	LRT	–	Pegangsaan Dua～Velodrome	5.8	6
11	(Reference) LRT JABODEBEK		–	Under Construction and planned（not opened as of May,2022）		

Source : KCI (Study team revision)

Figure 4-3 Outline of Urban Railway of Jakarta（as of May 2022）

(2) Status of each Operator

Item	KCI	MRT Jakarta	LRT JAKARTA
Transportation area	Responsible for wide-area transportation covering the Jakarta metropolitan area.	Responsible for transportation from the southern part of Jakarta to the office district in the center of the city.	Responsible for outer rim transportation, from the North of Jakarta to the East.
Development background	Converted into an urban railway by electrification and double tracking of Jakarta suburban sections of the national railway company (KAI), the parent company of KCI.	Japanese ODA provided from construction stage through to opening.	Light rail transportation built with the support of South Korea.
Particular features	Currently operating over 1,000 used Japan-made commuter trains.	Japanese methods of management and maintenance firmly established.	This is an independent line that has no connection with other urban railways such as KCI and MRT.
Operating model	Vertical separation (KCI responsible for operation and rolling stock maintenance, KAI for infrastructure maintenance, and government ownership)	Vertical integration	Vertical separation (LRTJ responsible for operation and maintenance, Jakarta State for infrastructure ownership)
Passengers carried (pre-pandemic)	More than 1 million per day	900,000 per day	4,500 per day
Future route expansion plans	Work is currently underway to enhance transport capacity, such as double-tracking and elevating terminal stations.	As Phase 2 of the currently operating North-South line, lines are being extended in northern Jakarta. In addition, an East-West line is also being planned.	Plans have been toned down due to the imprisonment of the former Governor, who had touted the plan for a line extension of about 200km within Jakarta.
Condition of aging of equipment	Other than some difficulty in procuring parts for old rolling stock, no particular problems are evident.	The lines have only been open for just over three years, and there was no specific mention of any problems associated with aging in the hearings that were conducted.	

Figure 4-4 Status of each Operator

(3) Current Operational conditions, issues, needs and applicability of Japanese technology

Table 4-6 Examples of Japanese corporate initiatives (Nippon Koei)

Item	Description
Background	Nippon Koei has signed an **MoS in the field of MaaS with PT Jakarta Lingko Indonesia**, the company responsible for the integration and operation of transportation payment systems in the Jakarta metropolis. Verification of the **feasibility** of the initiatives.
JST view	1. Application in the **formulation of** highly convenient and comfortable **train operation plans** 2. Application in the **formulation of maintenance plans** that minimize the impact on passengers 3. Application in the **formulation of facility and equipment plans** corresponding to

Item	Description
	future operation plans

Table 4-7 Examples of Japanese corporate initiatives (JR East Rail Car Technology & Maintenance)

Item	Description
Background	The company's overseas business is **"sales of rolling stock parts" and "local after-sales service."** Verification of the **collaboration** between this business model and the **maintenance of local used Japanese-made commuter trains.**
JST view	Regarding maintenance related support, it is essential that **"supply of maintenance parts" and "technical support" be integrated**, from the perspective of **providing reliable and continuous support**. In this sense, **the company's business model** may be described as an **extremely effective initiative**.

Table 4-8 KAI challenges and support methods

Classification	Challenges	Support schemes		Support methods
Station facilities	**Deviation** between current equipment specifications and **operational status**	Technical cooperation	Equipment procurement	Support for s**tation facility improvement work**
			Specialist dispatch	***Support for the formulation of equipment repair plans that reflect issues laterally across** operation and maintenance departments. *Support for the **creation of data sharing mechanisms** that can be used as the **basis for making decisions** on problem solving. (**Nippon Koei's efforts** are a good example)
Power	**Insufficient substation capacity** due to an increase in the number of trains in operation	Technical cooperation	Equipment procurement	Support in **substation reinforcement work**

(Note: Regarding this matter, issues related to KAI have been arranged and described from the results of the on-site hearing with KCI.)

Table 4-9 KCI challenges and support methods

Classification	Challenges	Support schemes		Support methods
Rolling stock	**Difficult to obtain parts** for old equipment	Technical cooperation	Specialist dispatch	**Replacement of old and difficult to maintain equipment only**, and support for **life extension of rolling stock**

Classification	Challenges	Support schemes		Support methods
				One example is **JR East Rail Car Technology & Maintenance's business model for KCI.**
			Equipment procurement	Support for the **provision of parts and materials needed for maintenance**
	Response in the event of **the new introduction of European standard rolling stock**	Technical cooperation	Specialist dispatch	Support for the **utilization of Japanese-style maintenance know-how** built up by KCI so far (Involving the state-owned company INKA)

Table 4-10 MRTJ challenges and support methods

Classification	Challenges	Support schemes		Support methods
Rolling stock/ Electricity	**Daily troubleshooting** (Noise, abnormal wear and tear, etc.)	Technical cooperation	Specialist dispatch	* Advice on troubleshooting faults and breakdowns * Support with failure warning sign analysis, etc.
Rolling stock	**No issues** with **regular inspections** (Note 1)	Technical cooperation	Specialist dispatch	* Support for overall inspection 4 years after opening (Note 2) * Perform while maintaining the flow of OMCS2
Train operation	Dealing with **transportation of large numbers of passengers at the time of special events**, etc.	Technical cooperation	Specialist dispatch	**Support based on Japan's wealth of experience, such as creating temporary timetables and train operation management.**

(Note 1: This is because the important parts inspection has been completed successfully with the support of OMCS2. The important parts inspection is a regular inspection performed on main parts.)

(Note 2: The overall inspection is the largest periodic inspection performed on the entire rolling stock equipment.)

Table 4-11 LRTJ challenges and support methods

Classification	Challenges	Support schemes		Support methods
Technical overall	**Insufficient post-opening support from S. Korea,** the construction supporting country	Technical cooperation	Specialist dispatch	Since the equipment is non-Japanese, **it is difficult to provide details support for the current system.**
	Lack of technical skills of among employees who are graduates of railway vocational school	Technical cooperation	Specialist dispatch	It is a good idea to provide **human resources development support**, such as the **acquisition of basic maintenance knowledge.**
			Training in Japan	**Basic skills acquisition support through on-site experience in Japan**

4.1.3 Kuala Lumpur, Malaysia

(1) Introduction

Currently, the railway network that spans the whole of Malaysia and covers from the border with Thailand to the eastern and western coasts of Malaysia, with part of the network extending to Singapore. Meanwhile, the Klang Valley Integrated Transit System is the heart of the urban railway network, linking the Kuala Lumpur metropolitan area, consisting of Kuala Lumpur and its environs. As shown in Figure 4-5, this network consists of two Malay Rail commuter lines serving the suburbs of Kuala Lumpur, an airport connection line, LRT, MRT, monorail, and BRT.

As of 2012, the usage share of the public transport (railway, bus, and taxi) among all commuters in the Kuala Lumpur metropolitan area remained to be substantially low at 12%.

With a view to raise the usage share of public transport to 40% during peak hours in the morning, new construction and extension of railway lines and promotion of train use by installing park and rides are being conducted.

Line	Serembam Line No.1	Port Klang Line No.2	Skypark Link No.10	KLIA Ekspres No.6	KLIA Transit No.7	Ampang Line No.3	Sri Petaling Line No.4	Kelana Jaya Line No.5	KL Monorail No.8	Kajang Line No.9
	KTM Kommuter		Airport Link			LRT			Monorail	MRT
Owner	Perbadanan Aset Keretapi (Railway Assets Corporation)			Express Rail Link Sdn Bhd		Prasarana Malaysia Berhad				
Operation and Maintenance	Keretapi Tanah Melayu Berhad (KTMB)			ERL Maintenance and Support		Rapid Rail Sdn Bhd				
Length (km)	135.0	131.0	26.0	59.8	59.8	45.1		46.4	8.6	51.0
Station No.	26	34	3	3	6	18	29	37	11	31
passenger (Unit :ten thousand)	8.3		0.0	0.6	1.8	17.8		25.9	3.4	17.5
Opening	1996/8	1995/8	2018/5	2002/4	2002/6	1996/12	1998/7	1998/9	2003/8	2016/12

Figure 4-5 Railway systems comprising the Kuala Lumpur Integrated Transit System

* In addition to the above, on June 16, 2022, Phase 1 (13 stations between Kwasa Damansara and Kampung Batu) of the MRT Putrajaya Line (Line 12: MRT Line 2) was partially opened.

(2) Special characteristics of the railway business

There are two main characteristic features of Kuala Lumpur's railway operators. The first point is that all routes use the vertical separation system to separate infrastructure and operations. In Kuala Lumpur, the asset-owning company and the operating / maintenance companies exist side by side, and all operating / maintenance companies except Malay Railway are subsidiaries of the asset-owning company. The second point is that, with the exception of the Kuala Lumpur International Airport Railway Link and Malay Railway-related lines, all operators are under the umbrella of the Ministry of Finance. This is largely due to the fact that the government bailed out the LRT2 line and monorail, which had been operating with private sector funding since the 1990s, and had suffered a deterioration in their financial situation, and the government subsequently improved the line and became the owner of the company.

Any financial concerns in Kuala Lumpur apply not only to past railway operators, but also to the current Malaysian government. This can be seen not only in the review of new line construction plans (cost reduction by reviewing transportation capacity and equipment specifications) for the Kuala Lumpur Integrated Transit System, but also in government level projects, such as in the repeated stop-start of contract negotiations for the high-speed railway project with Singapore.

The lines under construction / planning for the future include the LRT1 line, currently under construction, and the MRT loop line, currently being planned. However, the financial concerns mentioned above are also affecting new line plans. For example, on the Shah Alam line (Line 11: LRT3) currently being built, the construction costs came under review by the new administration of Pakatan Harapan in 2018, after the start of construction. As a result of this review, the number of cars per train, the total number of trains, and the number of stations were reduced, and the transportation capacity was halved from the original plan. Such a review means that the national plan itself to increase the transportation ratio of public transport will be swayed by uncertain financial conditions.

Participation by Japanese companies in Kuala Lumpur has included Hitachi Ltd. at the start of the

monorail construction (although they withdrew due to the Asian financial crisis), and orders received for track equipment on the MTR line (Mitsubishi Heavy Industries). Meanwhile, Chinese and South Korean companies have played the central roles in terms of rolling stock. In consideration of the fact that the main components of the business are overseas suppliers, it may be said that the level of affinity between Japanese companies and the railway operators is not very high at this moment in time, in terms of the field of maintenance.

4.1.4 Istanbul, Turkey

(1) Istanbul's urban railway situation

1) Overview

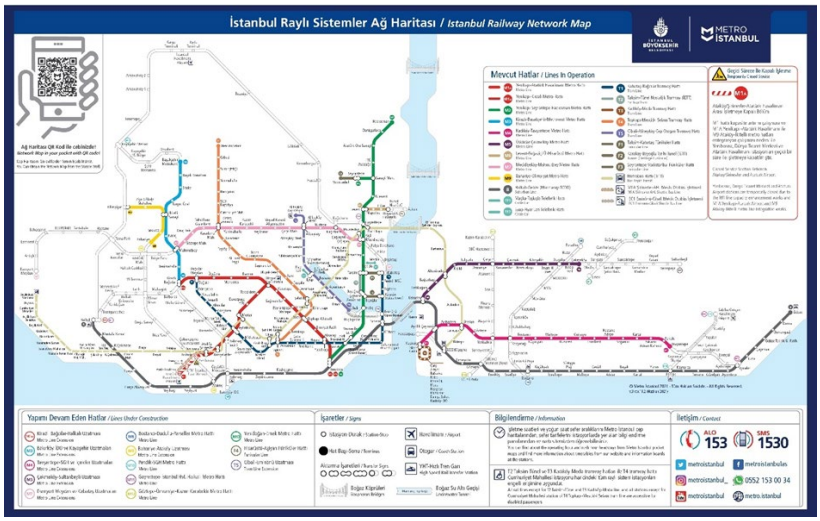
Istanbul is Turkey's largest city, the center of Turkey's economy and cultural history, and one of the largest cities in Europe.

Its public transportation, which serves an area with a population of about 15 million and about 5,000 km2 wide, comprises a blend of buses, rail transportation, cable cars, and ships. Figure 4-6 shows the transportation route map of Istanbul. Further expansion is planned, with Istanbul's railway network expected to reach 805.23km by 2023, growing from 262.15km in 2022.

1) Individual routes

Istanbul is served by three types of underground railway, full scale subways, small scale subways and underground cable cars. There are also trams and suburban trains. In terms of commuter railways, the Sirkeci to Hadımkoy route opened on the European side in 1872, followed by Haydarpaşa to Izmit on the Asian side in 1873.[1)] The full scale underground railway is called the Metro. The M2 Line was opened as a full scale underground railway in September, 2000, departing from Istanbul and running between Taksim and 4. Levent, a distance of some 7.9 km. The entire line was constructed underground by excavation, and is designed to withstand a magnitude 9 earthquake.[2)] Currently, excluding M8, the operation extends to Line M9, and the construction of M10 to 13 is also underway. Meanwhile, there are some routes that have been in operation for more than 30 years. Line M1 was opened in 1989 as a light metro line. The oldest underground railway in Istanbul is the underground cable car, F2, which opened in 1875.

In 2013, the underground section of the Bosphorus Strait Railway Development Project (the local name of this line is Marmaray) opened. For the underground section, four tunnel construction methods were adopted (strait section: submerged tunnel method, land section: shield tunnel method, stations: cut and cover, and NATM methods).[3)]



Source: METRO iSTANBUL website[8]

Figure 4-6 Istanbul suburban railway map

[8] https://www.metro.istanbul/en/YolcuHizmetleri/AgHaritalari

(2) Turkey's infrastructure environment

Turkey has already achieved a level of economic growth, with a per capita GDP of US $ 9,370 (2018), and further growth is expected, due to the nation's large population and large proportion of young people. Turkey's 11th National Development Plan (2019-2023) aims for Turkey to "join the ranks of developed countries" and "to increase GDP per capita to US $ 12,484" by 2023, the 100th anniversary of the founding of the Republic.

Turkey is one of the world's most earthquake-prone countries, with large earthquakes occurring frequently in recent years, such as the Izmit (M7.6) and Düzce (M7.2) tremblors in 1999, and a large M7.2 earthquake in eastern Van province in 2011. Turkey places great importance on countermeasures against earthquakes and other disasters, and the country's national development plan lists disaster management as one of its items, and promotes a range of disaster prevention efforts.[4)] In 2005, seismic-proofing construction was carried out on large bridges in Istanbul, including the Second Bosphorus Bridge and the Golden Horn Metro Bridge, both of which span the Bosphorus Strait.[5)]

(2) Operational statuses, challenges, needs and potential for Japanese corporate involvement

1) Turkish State Railways

The Turkish Ministry of Transport believes there is a need for the modernization of Turkish State Railways. The background to this is that there are many non-electrified sections and there are issues with the signaling system. In the future, the intention is to expand freight operations, and efforts to liberalize the railways will also focus on freight transportation. If the freight operation of Turkish State Railways is to be increased, there will need to be action taken on the plant and equipment side also. It is envisaged that infrastructure management will increase in importance, and the role (burden) of Turkish State Railways will expand accordingly. For example, with regard to tracks, the frequency of maintenance in response to track irregularity (displacement) and track member damage will need to be increased so that tracks can withstand cars with heavy freight loads. In some cases, it may be necessary to upgrade to a higher standard track. Since the modernization of Turkish State Railways plant and equipment will principally involve electrical equipment and track, and the policy is to make the best use of existing civil engineering structures, it may be expected that maintenance operations, such as the inspection and repair of tunnels and bridges over time will become ever more important.

2) Metro Istanbul

The rapidly expanding rail network will require the recruitment and training (quantity and quality) of operation and maintenance staff. In addition, it will also be necessary to expand safety and security (software and hardware) in order to cope with many more passengers. More than 20 years have passed since the opening of the M1 and M2 lines, and it is expected that the amount of work on the maintenance of both tracks and civil engineering structures will increase going forward. Ballast replacement is something that needs to be carried out over time, and is said to have been a difficult task. With regard to the tram routes, the number of passengers greatly exceeds the number that they were designed for, and the load on the track is greater than the design load, so the amount of maintenance is increasing.

1) Common needs

Since Turkey is one of the most earthquake-prone countries in the world, like Japan, it is conceivable that Japanese construction methods such as the reinforcement of elevated section support columns and of masonry retaining walls could be applied. In Japan, where there are there are many restrictions on construction space in urban areas, there is a history of carrying out seismic retrofitting work while keeping trains running normally, and it is conceivable that Japanese construction methods could find application in cities like Istanbul, were there are sections that are already in operation.

4.2 Overseas Expansion of O&M

(1) Importance of Infrastructure Maintenance

1) Civil structures

It is difficult to completely rebuild railway civil structures (e.g., tunnels, elevated sections), considering the potential financial and social impacts of service suspension along the section. In addition, there are already existing structures in city centers that may pose challenges in securing construction space. Therefore, in order to ensure the reliable performance and prolong the useful lives of these civil structures at low cost, it is necessary to carry out assessments through regular inspections, timely and appropriate repairs, and necessary reinforcements.

2) Tracks

Railway tracks directly impact the safety of train operations. These deteriorate faster than other railway infrastructure, so regular repairs are required. To extend the repair cycle at a low cost while maintaining the performance of the tracks, it is necessary to understand the deterioration progress by conducting regular inspections and timely repairs.

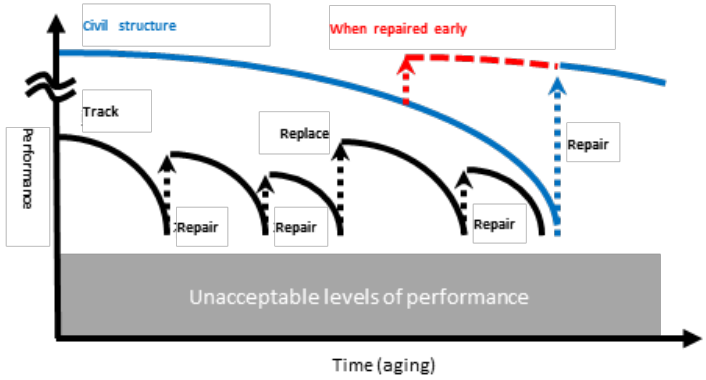


Figure 4-7 Changes in Performance Over Time (RTRI, 2013)

(2) Management Levels

A basic maintenance plan can be formulated at first. Once inspection data and technical knowledge within the organization is acquired over time, a higher level of maintenance management can be reached.

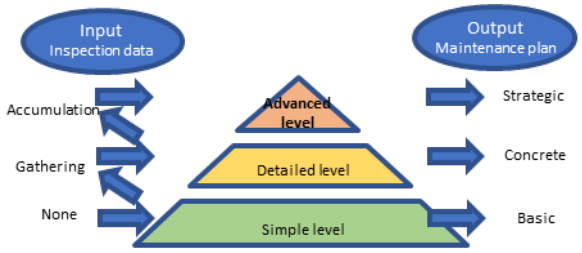


Figure 4-8 Infrastructure Maintenance Management Levels (Infrastructure Maintenance)

(3) Necessity of Maintenance System Development

An established maintenance system that is sustained and followed will promote proper and sustained upkeep of assets and processes. Alternately, the absence of such a maintenance system will result in an uncertain outlook for the railway system even if there are no current apparent problems. In a business environment with standards, budgets, personnel, and human resource development are stretched, it is necessary to develop a maintenance system in the future even if at present, there are no

events that hinder operations.

In Japan, implementation items are based on prevailing laws, standards, and regulations drawn up by the government, railway operators, and other stakeholders. One such implementation item based on these is maintenance.

Table 4-12 Maintenance Laws, Standards, and Regulations in Japan

Entity	Type	Title
State	Ministerial ordinance	Technical Regulatory Standards on Japanese Railways
	Notice	Notification Regarding Regular Inspection of Facilities and Rolling Stock
Railway operator	Regulations	Implementation standards (created by each company)
(Railway Technical Research Institute)	Standards	Maintenance standards for railway structures
Railway operator	Manuals	Inspection method, maintenance work method, and other manuals are formulated according to the situation of each respective company

(4) Expansion Possibilities

- **Database use for maintenance management**

For infrastructure maintenance, it is important to diagnose based on a variety of specifications (e.g., facility material, construction method, inspection, and repair history), the management of which is a common practice by many Japanese railway operators. In order to slow down deterioration, lengthen the period between needed repairs, and generally prolong the useful life of infrastructure to maintain performance, it is necessary to regularly inspect the degradation and determine its extent, carry out appropriate evaluations, and conduct adequate repairs and reinforcements as needed.

- **Proven inspection system and repair method**

In Japan's railway infrastructure, a unified inspection system has been established through the application of technical standards. Individual railway operators have established a series of maintenance cycles for inspection, appraisal, repair planning, and conducting actual repairs. By applying both the Japanese inspection system and proven repair methods overseas, it is expected that reliable maintenance cycles can be implemented. The initial assumption is that by establishing and implementing basic inspection and repair systems applicable to all lines and organizations, the needed practices and techniques will naturally be developed. This can then be further expanded as the conditions or requirements evolve.

- **Support for technology establishment**

For maintenance management, it is necessary to consider the local climate, environmental conditions, usage conditions as well as the details of the design and construction of a structure. Based on extensive knowledge and experience, engineers involved in infrastructure management also need to develop a deep sense of practical reasoning or imagination. With the international expansion of infrastructure management, transfer of inspection, diagnostic, and also specific technologies are expected. Furthermore, knowledge on management approaches, application of acquired data, and technologies accumulated from on-the-job training need to be strengthened.

- **Utilization of advanced technology**

Basic knowledge and experience are important for infrastructure management, but the development of technologies that support this field continues to evolve. The use of tablet terminals and augmented reality (AR) technology, the inspection of infrastructure with drones, and monitoring of track conditions by ordinary operating trains are just some of the many examples of these advanced technologies. By utilizing these technologies, inspection data can be collected efficiently and will lead to improved capacities to identify problem areas and optimize repair plans.

Figure 4-9　Use of AR technology

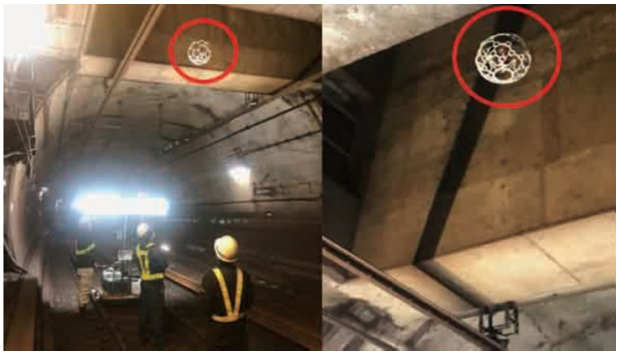


Figure 4-10　Using Drones for Inspection